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Report and attached documents provide evidence of the degree to which the project goals were achieved.

14. ABSTRACT The K-16 Engineering Pipeline: Engineering Success in STEM (K-16) project is a 1-year project funded by ONR to develop an engineering pathway of high school courses and requirements within the Hawaii Dept of Education (HIDOE) that leads directly to acceptance into the University of Hawaii College of Engineering (UHCOE) or other STEM-related technical training in Hawaii. This project addresses the need for a rigorous statewide Engineering Pathway of core courses and requisite teacher training support services within HIDOE to increase the number of "home grown" engineers and technicians who will remain in Hawaii for employment at Pearl Harbor, NAFAC, SPAWAR, and other non-DoD STEM-based companies. A process evaluation examined the capacity of K-16 to meet objectives and outcomes that establish and institutionalize an Engineering Pathway between HIDOE and UHCOE. K-16 also provides additional supports in the final year of the Engineering Success in STEM project to high school teachers in 6 complex areas: Castle, Kaimuki, Kealakehe, Leilehua, Moanaula, and Pearl City. This report summarizes K-16's progress toward meeting the objectives and outcomes at the end of Year 1.

The findings of the evaluation for K-16 confirm that it was successful in achieving all 6 project objectives and desired outcomes. The greatest achievement of the project was the establishment and institutionalization of an Engineering Pathway of courses that results in Hawaii public school students gaining direct acceptance to UHCOE. As a result of the partnership established between HIDOE and UHCOE, all 6 participating high schools offered the Engineering Pathway core courses to students the following year (AY2016-2017). K-16 also positively impacted teachers' confidence teaching the Engineering I course and capacity to design rigorous engineering-focused units. Overall, the results of the project provide conclusive evidence that K-16 was able to develop and engineering pathway that has the capacity to increase the number of students that pursue engineering as a major at the University of Hawaii.

15. SUBJECT TERMS
Professional Development, K-5, STEM, Curriculum, Engineering Design Process, Student Engagement, Problem-Solving, Creativity

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October 19, 2016

TO: Dr. Richard Carlin, Department Head
ONR Sea Warfare and Weapons Department

FROM: Katherine Kawaguchi, Project Director
Chaminade University of Honolulu

SUBJECT: End-of-Project Report for *K-16 Engineering Pipeline: Engineering Success in STEM (K-16)* Project (N00014-15-1-2450)

Thank you very much for your support for the *K-16 Engineering Pipeline: Engineering Success in STEM* Project (N00014-15-1-2450) and ongoing commitment to engineering education in Hawai'i public schools. The Project Objectives for Year 1 were to:

1. Define the requirements for the Engineering Pathway between HIDOE and UHM
2. Develop and pilot test the teacher training session curriculum
3. Involve teachers in collaborative development of rigorous engineering-focused units
4. Increase the number of high schools offering the Engineering Pathway core courses
5. Identify and develop additional engineering-related training sessions needed by teachers
6. Develop an agreement between the HIDOE and UHM College of Engineering that specifies the outcome of students who met the college requirements

The final reports included in this transmission include:

1. K-16 Final Evaluation Report – An executive summary of project outcomes
2. K-16 Education Brief – A dissemination product for internal and external parties
3. K-16 Appendices of Evaluation Reports – A list of related project documentation

The findings of the evaluation for the K-16 Engineering Pipeline: Engineering Success in STEM project confirm that the project was successful in achieving all six project objectives and desired outcomes. The greatest achievement of the project was the establishment and institutionalization of an engineering pathway of courses that results in Hawai'i public high school students gaining direct acceptance in the University of Hawai'i at Mānoa, College of Engineering. The institutionalization of an engineering pathway would not have been possible without the support of the Office of Naval Research and the Sea Warfare and Weapons Department.

Mahalo nui loa,

Katherine Kawaguchi

cc: Dr. Helen Whippy, Provost
Dr. Dale Fryxell, Interim Dean, Education Division

K-16 Engineering Pipeline: Engineering Success in STEM (K-16)
Evaluation Report: Year 1
September 27, 2016

Executive Summary

The K-16 Engineering Pipeline: Engineering Success in STEM (K-16) project is a one-year project funded by the Office of Naval Research (ONR) to develop an engineering pathway of high school courses and requirements within the Hawai'i Department of Education (HIDOE) that leads directly to acceptance into the College of Engineering, University of Hawai'i at Manoa (UHM) or other STEM-related technical training in Hawai'i. This project addresses the need for a rigorous statewide Engineering Pathway of core courses and requisite teacher training support services within the HIDOE to increase the number of "home grown" engineers and technicians who will remain in Hawai'i for employment at Pearl Harbor, NAFAC, SPAWAR, and other non-DoD STEM-based companies. A process evaluation examined the capacity of the K-16 to meet objectives and outcomes that establish and institutionalize an engineering pathway between the HIDOE and the UHM. The K-16 also provided additional supports in the final year of the Engineering Success in Stem (ESS) project to high school teachers in six complex areas: Castle, Kaimuki, Kealakehe, Leilehua, Moanalua, and Pearl City high schools. This report summarizes the K-16 project's progress toward meeting the objectives and outcomes at the end of Year 1.

Table 1. K-16 Project Objectives, Outcomes, Findings, and Conclusions.

Objectives	Desired Outcomes	Measures and Results	Conclusions
1. Define the requirements for the Engineering Pathway between HIDOE and UHM	○ Project partners will state and agree upon Engineering Pathway requirements	**Document Review** • College-Focused Engineering Pathway Program of Study documents required core courses, elective courses, and the Engineering Pathway courses (Grade B or higher): ○ Industrial and Engineering Technology Core ○ Engineering Technology I ○ Engineering Technology II ○ STEM Capstone	**Project Impact** • HIDOE approval of Engineering Pathway Courses • Institutionalization of an engineering pathway that details the types of courses and the minimum letter grade students need to progress from HIDOE into the UHM College of Engineering
2. Develop and pilot test the teacher training session curriculum	○ Project supports will prepare high school Engineering Pathway teachers to teach engineering core courses	**Teacher Survey** • Non-significant improvements in teachers' personal and peer attitudes toward the EDP and STEM teaching practice **Teacher Focus Groups** • Teachers reported that participation increased their understanding of the EDP and confidence teaching the Engineering I course curriculum	**Teacher Impact** • Results are positive, especially since 12 out of 15 teachers (80%) had little to no prior EDP experience before the K-16 • All future engineering teachers reported that ESS project participation helped prepare them to teach Engineering I

Objectives	Desired Outcomes	Measures and Results	Conclusions
3. Involve teachers in collaborative development of rigorous engineering-focused units	○ Teachers will create 3 units in teams (Math, Science, CTE) ○ Teachers will analyze projects in the Engineering the Future instructional materials	**Document Review** • Teachers developed six collaborative STEM units: CTE (3 units), Math (2 units) and Science (1 unit) **Teacher Focus Groups** • The following activities were valuable for unit development: ○ Working with teachers from the same content area ○ Receiving feedback from project staff and peers ○ Hearing from other teachers who had more experience ○ Working with teachers from other content areas • Teachers reported completing collaborative projects to identify standards addressed through Engineering the Future materials	**Teacher Impact** • The ESS project exceeded the desired outcome for Objective 3, with teachers working collaboratively to develop 6 STEM units for future implementation • STEM unit development was perceived to be one of the most useful aspects of the professional development • Teachers reported that collaborative projects helped them identify standards-based projects to implement next year
4. Increase the number of high schools offering the Engineering Pathway core courses	○ HIDOE schools will commit to offering Engineering Pathway core courses in 4 schools	**Document Review** • Emailed communication and school registration guides confirmed that Engineering Pathway core courses are currently being offered at all 6 participating high schools (Castle, Kaimuki, Kealakehe, Leilehua, Pearl City and Moanalua)	**Teacher Impact** • Objective 4 was exceeded with all 6 high schools (100%) offering Engineering Pathway core courses in SY2016-2017
5. Identify and develop additional engineering-related training sessions needed by teachers	○ Teacher training sessions will meet the needs of participating teachers	**Work Session Evaluations** ○ The ESS addressed teacher requests for additional information and the number of requests for clarification decreased by the second half of the year **Teacher Focus Groups** ○ A majority of teachers (12, 80%) requested a college level introductory engineering course in mid-year focus groups	**Teacher Impact** ○ Work sessions and curriculum resources were perceived as the most valuable aspect of K-16 participation ○ An introductory engineering course was offered through UHM and sponsored by the K-16 and ESS projects to increase teacher engineering content knowledge in summer 2016
6. Develop an agreement between the HIDOE and UHM College of Engineering that specifies the outcome of students who met the college requirements	○ Project partners will state and agree upon the outcome of meeting Engineering Pathway requirements	**Document Review** ○ Final Memorandum of Understanding with signatures by the University of Hawai'i at Mānoa, College of Engineering (CoE-UHM) and the State of Hawai'i Department of Education (HIDOE), Superintendent of Education ○ HIDOE and CoE-UHM have agreed and committed to: ○ Designate a point of contact to administer the program ○ Provide annual summary of enrollment data ○ Monitor program effectiveness ○ Coordinate and attend an annual meeting	**Project Impact** • Requirements and necessary preparation for Hawai'i high school students to be accepted directly as an engineering major in the CoE-UHM (which is accredited by the Accreditation Board for Engineering and Technology)

Discussion

The findings of the evaluation for the K-16 Engineering Pipeline: Engineering Success in STEM project confirm that the project was successful in achieving all six project objectives and desired outcomes. The greatest achievement of the project was the establishment and institutionalization of an engineering pathway of courses that results in Hawai'i public high school students gaining direct acceptance in the University of Hawai'i at Mānoa, College of Engineering. As a result of the partnership that was established between the HIDOE and CoE-UHM, all six participating high schools offered the Engineering Pathway core courses to students the following year (SY2016-2017). The K-16 project also positively impacted teachers' confidence teaching the Engineering I course and capacity to design rigorous engineering-focused units. Overall, the results of the K-16 provide conclusive evidence that the project was able to develop an engineering pathway that has the capacity to increase the number of students that pursue engineering as a major at UHM.

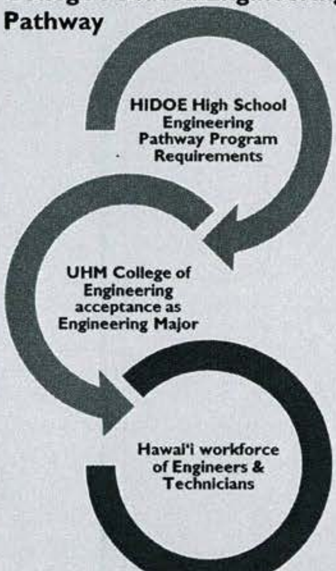
K-16 Engineering Pipeline

YEAR 1 **SEPTEMBER 2016**

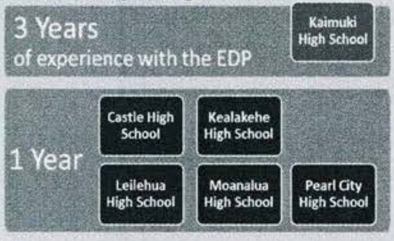
Project Overview

The K-16 Engineering Pipeline: Engineering Success in STEM (K-16) project is a one-year project to develop an engineering pathway of high school courses and requirements within the Hawai'i Department of Education (HIDOE) that leads directly to acceptance into the College of Engineering, University of Hawai'i at Mānoa (UHM) or other STEM-related technical training in Hawai'i.

College Focused Engineering Pathway



6 Participating Schools



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Obj 1

Define the requirements for the Engineering Pathway between HIDOE and UHM

HIDOE approval of Engineering Pathway Courses developed by K-16

Required Core Courses

- Industrial and Engineering Technology Core
- Engineering Technology I
- Engineering Technology II
- STEM Capstone

Obj 2

Develop and pilot test the teacher training session curriculum

100%

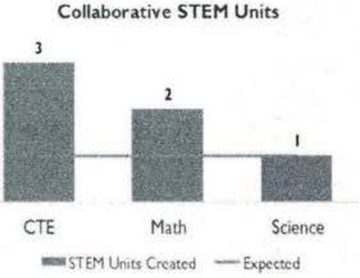
of teachers who planned to teach Engineering Pathway Courses reported that the ESS project helped prepare them to teach Engineering I next year.

Teacher Focus Groups

"I just appreciate the fact that there were so many practical tools that I was able to get from this program, like the rubrics and the projects... I have increased my confidence in teaching because of all the tools that I've received. That's been a really great thing that's happened to me with this program."

Obj 3

Involve teachers in collaborative development of rigorous engineering-focused units



Obj 4

Increase the number of high schools offering the Engineering Pathway core courses

100%

of schools are currently offering Engineering Pathway core courses

Obj 5

Identify and develop additional engineering-related training sessions

1

Introductory engineering course was offered through UHM in summer 2016

Obj 6

HIDOE and UHM College of Engineering specify the outcome of students who met the college requirements

Memorandum of Understanding by the University of Hawai'i at Mānoa, College of Engineering and the State of Hawai'i Department of Education

Established Engineering Pathway Program resulting in direct acceptance as an engineering major in the University of Hawai'i at Mānoa, College of Engineering

K-16 Engineering Pipeline: Engineering Success in STEM (K-16)
Appendices of Evaluation Reports for Year 3
September 28, 2016

Engineering Success in STEM (ESS) and the K-16 Engineering Pipeline
Teacher Mid-Year Focus Group Report
February 1, 2016

Overview

The purpose of this report is to inform two concurrent and connected professional development projects that aim to train teachers in the development and implementation of standards-based STEM curriculum units incorporating the engineering design process (EDP). Both projects were developed by Chaminade University, funded by the Office of Naval Research, and delivered in partnership with the University of Hawai'i College of Engineering.

The first project, the Engineering Success in STEM (ESS), is in the final year of a three-year grant. The ESS initially focused on middle and high school teacher knowledge, development, and implementation of comprehensive, integrated, standards-based instructional units that engage students in rigorous application of the EDP. This project was modified to expand participation to high schools in five other complex areas, which was seen as critical in helping the Hawai'i Department of Education (HIDOE) institutionalize engineering education. The second project, the K-16 Engineering Pipeline: Engineering Success in STEM, is a one-year project that supports the ESS through process objectives to establish an engineering pathway through collaboration and agreements between the HIDOE and the University of Hawai'i College of Engineering. The revised objectives for both ESS projects are listed in Table 1. This report summarizes the findings of mid-year focus groups with participating teachers to provide information about progress toward meeting ESS Objectives 1 and 3; and K-16 Pipeline Objectives 2, 3, and 5.

Table 1. Objectives of the ESS and K-12 Pipeline.

Engineering Success in STEM	K-16 Engineering Pipeline
1. Develop a deep understanding of the engineering design process (EDP)	1. Define the requirements for the Engineering Pathway between HI-DOE and UHM
2. To introduce teachers to the Engineering I and Engineering II curriculum map	2. Develop and pilot test the teacher training session curriculum
3. To facilitate the collaborative development of rigorous engineering pathway units based on the curriculum map	3. Involve teachers in collaborative development of rigorous engineering-focused units
	4. Increase the number of high schools offering the Engineering Pathway core courses
	5. Identify and develop additional engineering-related training sessions needed by teachers
	6. Develop an agreement between the HI-DOE and College of Engineering UHM that specifies the outcome of students who met the college requirements

Through the ESS and K-16 Pipeline, teachers participate in training and mentorship during professional development sessions (7 sessions/year), meet with their peers to plan STEM curriculum units during teacher-directed work days (2 substitute days/year), and consult with engineering and instructional mentors (as requested). Participating schools include six HIDOE public high schools. One school is in its third year of participation through the ESS (Kaimuki High School) and five are halfway through their first year with the ESS and K-16 Pipeline projects (Castle, Kealakehe, Leilehua, Moanalua, and Pearl City high schools). In total, 15 teachers participated including math, science, engineering, career and technical education (CTE), industrial and engineering technology (IET), and STEM resource teachers. In school year 2015-2016, 12 teachers (80%) were new to the project. As such, the project team made adjustments to the content of the comprehensive series of engineering focused professional development sessions to train new teachers in the EDP.

The evaluation of this project is both formative and summative. Focus groups are one method for collecting evidence of the implementation and effectiveness of professional development supports from the perspective of participating teachers. The external evaluator for ESS conducted focus groups halfway through the year to gather information that the Project Director could use to guide program improvement. Specifically, the project was interested in gaining information about the following:

1. Teacher understanding of and confidence with teaching the EDP
2. Project supports that were helpful in developing and implementing STEM units
3. Teacher perceptions about the value of developing their own curriculum units
4. Integration of the EDP into course content
5. Implementation of a college-focused engineering pathway program
6. Challenges and suggestions to address those challenges

This report summarizes the information shared by teachers to guide project planning and improvement for the remainder of the school year.

Methods

Two focus groups were conducted by the external evaluator in a private room during the fourth of seven planned professional development sessions. Focus group composition was based on the fact that two schools participated as integrated teams (comprised of engineering/technical, math, and/or science teachers). These two schools were also either currently offering, or planning to offer a STEM Academy (as reported by the Project Director). It was assumed that teachers with similar experiences with implementation at their school may have different perceptions of the training, curriculum design and EDP integration. The first focus group included seven teachers from the two high schools discussed previously, and the second had eight teachers from the remaining four high schools.

The evaluator conducted each focus group as a semi-structured interview which allowed participants an opportunity to discuss seven open-ended questions in a group setting (nine questions were initially planned, but time only allowed for a discussion of the first seven). Participants were able to speak in any order or pass if they had nothing to share. The facilitator briefly summarized responses and asked for additional thoughts or clarification before moving

to the next question. All focus groups were transcribed verbatim and analyzed qualitatively by coding teacher responses and quantifying emergent themes within and between focus groups.

Results

The findings included in this report are based on the experiences of high school teachers participating in the projects and do not represent the perspectives of all groups involved in this project (i.e. Project Director, staff, school administrators). Keeping this in mind, there are three important contextual factors to consider when interpreting these results. First, it needs to be stressed that 12 (80%) of the teachers were new to the project and did not have the first two years of EDP training and mentorship. This is in addition to varying levels of previous experience with engineering education and the EDP. Second, schools may be simultaneously implementing additional STEM initiatives. For example, two schools were either implementing or planning to implement a STEM Academy. Third, the HIDOE has other system level initiatives which affected teachers' experiences with the project, including the implementation of common core standards, the Standards Based Assessment Consortium (SBAC) standardized test, and end of course exams. The above information is intended to explain the circumstances that may contribute to these findings.

Teacher Understanding of the EDP

Teacher understanding of the EDP is seen as foundational in the development and implementation of STEM curriculum units. To examine current levels of understanding, teachers were asked to respond to a series of questions addressing positive aspects of the EDP, comfort and confidence teaching the EDP, and steps that seem challenging. In both focus groups, individuals were encouraged to consider any supports that might help to address the challenges discussed.

Positive Perceptions of the EDP. Teachers in both groups most frequently talked about the importance of teaching students a process for problem solving and higher order thinking. As one individual mentioned, "I like this process because I think it helps students and teachers to help spell out the thinking process. We kind of analyze and emphasize that part." Three themes emerged with second greatest frequency across groups, and included: engaging students through hands-on activities, solving authentic real-world problems, and focusing on improvement. One teacher shared, "I like teaching engineering. It's so much fun. Lots of hands-on, engaging, authentic learning. The kids are so smart and you can just see light bulbs going on all the time... and they're asking questions and I have to find the information. I do love it." Another built on the discussion of real-world problems and added,

> The engineering design process to me, is a tool that all students can benefit from [grades] K-20. It allows them to have that chance to explore real world problems, find solutions, and the unique thing that I think a lot of students benefit from is they realize that failing is good. It actually gets you to redesign something and improve your product, so that's different from just plain inquiry.

A couple teachers from each group also discussed the following two themes: job preparation for STEM fields and student creativity. As one pointed out, "What I like about this whole engineering in the curriculum is that this is where the future of jobs are going." Another teacher

in the same group mentioned, "What I really like about the engineering process is the amount of creativity that can be harnessed from it and I feel like that's what keeps me excited about it." Last, two teachers in the second group talked about the application of the EDP in many different content areas. One stated, "What I like about the engineering design process is that it is easily modified to be used in any sort of curriculum."

Comfort and Confidence with the EDP. Only teachers in the first focus group reported feeling comfortable or confident with the EDP. First and foremost, several teachers described feeling confident because they had already taught the EDP (two through the ESS project and another in teaching a high school engineering course). Having two years to design and implement the EDP through the ESS project was clearly a benefit in that one teacher described, "I feel pretty confident. I think I've gone through it at least five times now because we were required to go through it each semester." Another shared, "I feel pretty comfortable with all the steps because we've gone through it last year. My students went and did the whole process and we've done it and we started it again this year, so I'm pretty confident in all the steps." The teacher who had used the EDP previously also pointed out that participation in the projects this year was still valuable. This person shared,

> I am comfortable going through the engineering design process with the students, but I'm reminded to make sure that the students understand what [steps] they are doing at the time because I've done it so often with the different classes that I'm teaching... It's more me realizing that I cannot skip steps and be able to tell them what process they are learning and explaining it to them.

Two teachers without previous experience with the EDP also reported feeling comfortable because certain steps align with the scientific method. One participant replied, "I feel pretty confident with Imagine and Create because, like teacher said, it aligns with the scientific method really well." This being said, the Improve step was still very new. As another teacher reflected, "I used almost all the engineering design process stuff except for the redo – because it's almost the scientific method… the only thing that looks substantially different is the redo. And that's my favorite part... I didn't think about that at the time. I hadn't seen the EDP then."

Challenging Aspects of the EDP and Suggested Supports.

Teaching the Improve Step and the Gantt and Pugh Charts. Teachers in the first group were able to identify aspects of the EDP that might be challenging to teach. Most frequently, they described a lack of confidence teaching students about the Improve step. One teacher who has been teaching the EDP explained,

> The Improve step is the hardest. I never do it in my first semester project, but I always do it in my second semester project. It's tough for [students] because sometimes they don't know how to improve something because they don't know what made it work in the first place, so they just try a different design and try it out… because they don't know the principle of what makes something or that thing work.

Another teacher agreed, "That's probably the main thing that the students have difficulty with and a lot of it stems from their lack of background knowledge." This issue was linked to student knowledge of engineering principles for several participants. Two individuals also explained

that they had not had a chance to go through the Improve step during the professional development sessions. As one person shared, "The step that I find the most challenging is the Improve step and I think it's because most of my experience with the EDP has been at these meetings and we don't usually get through that step, so that's the one I find most challenging."

Similar with the previous two years in the ESS project, a majority of teachers in the first group reported a lack of understanding and confidence with the Gantt and Pugh charts. Specifically, these teachers need help in understanding how to teach students to use these organizational methods. As one person admitted, "I think critical in [the Gantt and Pugh charts] is teaching motivation to want to use those because I'm not motivated to use those. So how in the world am I going to motivate my students to want to use them?" One person would also like more time to practice developing specifications for a design solution.

To address these challenges, teachers in this focus group suggested that the project team dedicate time during the professional development sessions to go through each EDP step, which would allow time to cover the Gantt and Pugh charts in greater detail. Although teachers who were in their third year of participation had the opportunity to focus on each step through the ESS, the new teachers felt like they needed this as well in order to develop a deep understanding of the EDP. This suggestion is illustrated by the following conversation:

> Teacher 1: "Maybe we could have projects at our [professional development] sessions where they emphasize certain aspects of the EDP. The first session we only focus on defining the problem, or making the specs because I still need to understand how to make specs."
>
> Teacher 2: "I think the suggestion of going piece by piece is really good. Maybe if we started, like how on the first day we did a whole round of the EDP just so we could get a preview of what the process is and then from there on out, for each of the [professional development sessions], breaking it down."

Teaching about Instructional Time Management to Help Teachers Address and Peer Sharing to Prioritize EDP Steps. This theme came up in both focus groups, although those with some experience with the EDP discussed it more extensively. Most frequently, teachers discussed the time required to orient students to the EDP, get through all the steps and address other expectations for their STEM units (inclusion of the Gantt and Pugh charts). Regarding the time to initially teach students about the process, one teacher put forth,

> Thinking about the size of my class and trying to get [students] to do any of the early steps individually and then in their groups, feels a little daunting... because they get excited about their ideas and so they want to start sharing them... We see that with our own experiences when the teachers are doing [EDP challenges]. We rarely do the individual steps. So I imagine it's going to be hard to get the kids to do that too.

A second teacher agreed in stating,

> The other part that seems challenging, I couldn't really see it until I was doing the mini unit... Even getting the students to learn about the Gantt chart and the process that we were going through with them. To have them, in that amount of time, try to get up to speed. You can't get everything in one [project]... The process, to finish on time, [in] the

> timeline that we tried to put, and to meet it? It's difficult but it can be done. I'm going to skip steps. We just can't fit everything of what's expected in the EDP in that time - so it takes time.

This point was reiterated in another focus group when one person shared,

> The [EDP] process is great, but I think a lot of people struggle with the actual management of time within each of the steps. If you're solving real world problems and improving upon these problems, the time aspect, no matter how much you try to train people on it, the problem is still there. To manage time in each of the steps is really hard.

Furthermore, the teachers who had been implementing the EDP through the ESS project reported that they did not have time to go through each of the steps with their students. As one teacher explained, "Sometimes we don't have enough time, so we don't get to the improve portion of things... With the last project I did... we actually didn't do the improve portion. I had [students] write down what they would do to improve it, but we didn't actually improve the prototype."

To address this challenge, participants posed two suggestions. First, teachers in both focus groups would like to have some instruction related to time and classroom management. One person specified, "I was looking for more solutions that better teach teachers how to manage their time or to see when the project needs to move forward. And even in this workshop... I mean the projects in here run on times and it's very hard to manage." Both groups spent a good amount of time talking about how to prioritize aspects of the EDP and keep within the time allotted for a particular project. One person wondered, "What gets cut out? Exactly. That takes practice. That's something you can't really teach, and I was looking for that." Another person wondered whether every design challenge requires a Gantt and Pugh chart. This person admitted,

> I love the Pugh charts and the [Gantt] charts, but... every single mini lesson has a spec chart and a Pugh chart that we have to do... I don't know if that's the case. I mean if it was the engineers who designed the lesson, is that what they mean? Does everything need a Pugh chart and a Gantt chart?

The second suggestion was to allow time for teachers to share their experiences and lessons with each other during the professional development sessions. This suggestion came out of the fact that two teachers were able to share the ways they scaffold the learning process for their students with other focus group participants. One described,

> I do only a few steps. I might start off with the Ask, and then I might do the Imagine, and then I might strip down certain portions of it. Instead of having [students] do the Gantt chart and do the Pugh chart, I'll eliminate that until a future project. So eventually we'll go through the whole thing and then we'll include everything. The final project has everything in it. And so that I've found to be pretty effective in teaching it to the kids.

Another teacher shared, "I do a low level of everything, but I can tell what [teacher's] kids have done in detail because they understand that part – because he goes part by part. Whereas I do everything at a level 1 and then try to do a level 2 the next time around." This conversation

spurred all teachers in this focus group to agree that time for teacher sharing is needed. One person extended this request in stating, "I really like that idea and I'd like to see all [teacher's] lesson plans."

STEM Curriculum Unit Development

ESS Objective 3 and K-16 Pipeline Objective 3 aim to have teachers create and implement STEM curriculum units that incorporate the EDP. To achieve this goal, teachers in their third year are expected to develop six units over the course of three years (two during SY 2015-2016). Teachers in their first year are expected to develop two units by the end of this year. These focus groups are intended to describe teacher experiences with STEM unit development, which also could inform K-16 Pipeline process Objectives 2 and 5. To do so, the focus groups discussed the project supports that were helpful in unit development, challenges encountered, and suggested improvements or supports. Furthermore, teachers were asked to reflect on the value of developing their own units versus using a prescribed curriculum.

Project Supports that were Valuable for STEM Unit Development.

Experiencing the EDP during Professional Development Sessions. Teachers in both focus groups most frequently reported that the most helpful aspect of the project was having opportunities to go through design challenges, observe how to teach the EDP, and be exposed to sample projects they could use with students. As one individual commented, "These sessions are the most helpful to me because we get to go through it ourselves and watch how [facilitator] teaches it and I get to pick and choose what I like. I like how she taught this and I can implement that in my classroom." Another person mentioned, "I really appreciate that they teach by modelling. I can't tell you how that doesn't always happen in a professional development and that's really important to me." In another focus group, a participant stated,

> Having us try [design challenges] out... what I'm able to do is take the lessons that we're doing here and kind of guinea pig them on the kids that I have now to see how it's going to work out and work out the kinks... I have a bank of really good things – lessons that I can start off and plan already."

Several others appreciated being able to learn the EDP as a student. One teacher added, "I also like being the student, so I can see things from their perspective and it helps me to teach to them better." For some folks, being able to experience a design challenge helped them to consider group dynamics. As one person described,

> I think going through these [EDP] projects... I was watching the techniques and how one can get tunnel vision in seeing what might be the best solution... Learning from that, it's not always about the solution, but more of listening to everybody else and observing. That is, I think, the biggest lesson that I came away with... the frustration at least puts me in a category with the students, empathy wise.

Providing time to Work with other Teachers on Unit Development. Both groups spent time talking about the time provided for lesson planning, both during the professional development sessions and, more importantly, through substitute days provided to participants. One person explained,

> It's also really helpful to have the sub pullout day for [teacher] and myself to work on our project because trying to do that during a prep time is not realistic. Like during our prep periods... it's not enough time. To sit down and just be able to focus on the project for a day is great because we have to do all our teacher stuff during prep periods.

In another focus group, one person reflected on being able to design deeper units of study because they were given planning time:

> The time that we were given to work with each other on the unit plan was really good... To be honest, if I didn't have that opportunity to work with other people, I don't know if I would have done a formalized lesson plan just for that class. I might have just broken it down into small projects, but this put the whole thing into perspective. A much larger look at what it can become.

Last, a majority of participants agreed with the following sentiment about the critical nature of planning time as a project support. This person stated,

> When I look at it from a district level, support for the teachers is unique about this project [and] should be known... The time built in for collaboration and to actually work on your lessons or mini unit – it's rare to see projects that support the teacher [on] their instructional piece with feedback on the lesson, time to work with others, and to actually have this workshop with that kind of piece built in. Because the majority of the workshops out there, you don't get that time. It's you come in, you do it, you do it on your own time. But to see it embedded inside the day is pretty neat.

Even teachers who had not yet used their planning days reported looking forward to utilizing the planning time as they got further along in their unit development.

Receiving Feedback and Resources to Improve STEM Curriculum Units. The third theme that emerged from the discussion in the first focus group related to the fact that teachers were able to receive feedback to improve their units. This included suggestions for to include common core standards and benchmarks, additional resources and materials. Most often, these supports were provided by the Project Director and curriculum design experts. One individual shared, "The most useful thing that they do is have somebody look over my EDP. The suggestions are always positive. They are always really good. They put in standards that I didn't see." Another person further explained,

> I think the feedback they provide is timely... We had a hard time writing it because it's our first year... but they were very positive and they always want to help out. [Project Director] will go find resources and I really appreciate that. I think we didn't know what questions to ask because we didn't know what we were doing so we didn't know what resources we needed.

This was especially helpful given the pressure of other system and school initiatives. As one teacher commented, "[Project Director] is excited to help us. She tries not to put extra stuff on us. She's probably experienced working with so many teachers over the years and a lot of time is the footwork of finding people, and contacts, and resources." One person also appreciated the help of engineer mentors for a similar reason in stating,

> I think the engineers that are in here are super supportive. They've provided us with lists. They provided us with how to do this and websites and that kind of a thing... where if I learned it on Friday, I could definitely do it on Monday just because of all the stuff that they have already given us. So they do all of that legwork that as a teacher would be a barrier for me in terms of actually doing the project.

Last, one individual who was new to engineering education mentioned the importance of connecting the EDP to other forms of scientific inquiry that teachers are familiar with. This person shared, "

> Some of the supports that I found useful were the crosswalks between what I already know with the new things I was learning about the engineering design process. For example, the whole process being comparable to the scientific inquiry process. Yet, there being a difference between the two. That was really useful for me to see that and the supports when it came to the benchmarks and the science standards that are coming in – the new science standards. I thought that was useful.

Collaborating with and Learning from More-Experienced Teachers. Teachers in both focus groups reported that they learned from more-experienced teachers, which provides some support for the value of collaboration that the ESS and K-16 Pipeline projects built into their objectives for unit development. As one individual excitedly claimed, "Talking to [other teacher] has been a big help... My whole 4th quarter is based on a conversation that we had. So I think, being able to hear other people's comments and suggestions and ideas has been the biggest take away that I've gotten from this [fourth] session." In the other focus group, another person iterated, "Working with the other teachers was great... We got to work with teachers from other schools. I think that really helped."

A second aspect of learning from their peers was being able to see the types of engineering design challenges that teachers developed with the ESS in Years 1 and 2 by observing a student symposium with a sample of students from Kaimuki High School. For a couple of people in the second focus group, the mock symposium was motivating because teachers could see how teachers implemented the EDP, the end products students designed, and the partnerships made with other community organizations. As one teacher shared, "I liked watching that symposium and seeing how [Project Director] can find someone to be a resource for the students or whatever type of engineering or the project that they're doing. That's one thing that a lot of our schools don't have is that outside partnership with other companies."

Challenges and Supports needed for STEM Unit Development. Teachers in both focus groups were in agreement on the challenges they could foresee to unit development and implementation. These challenges related to needing more supports to teach them how to teach the EDP (especially in ways that rely more on modelling and less on lecturing), as well as supports to help them develop or verify their engineering knowledge. This is illustrated by the following representative comment, "Just in regards to modelling and teaching... I think [facilitator] could model even more because I hear that we're not supposed to lecture so much... I never figured how to get that information across without lecturing. I'd like to see more of that magic happen." In another focus group, a participant reflected on their own background knowledge in stating, "My main concern as a teacher who does not have an engineering background is that I don't want it to be like engineering design for dummies – just the basic

trying to get through it so I can get through the process. I want it to be relevant and rigorous." With such a high level of agreement, individuals spent most time discussing potential supports or project improvements for future cohorts.

Participating in a University of Hawaii Engineering Class. The vast majority of comments were about a desire to enroll in an introductory engineering course at the University of Hawaii, College of Engineering. This was very surprising to the evaluator, given feedback on previous projects that afforded this opportunity to elementary teachers. However, it should noted that 12 teachers (80%) indicated that they would be interested and willing to enroll in a course if it was available. This may be due, in part, to the level and complexity needed to teach high school level courses. The first teacher to initiate this conversation in the first group suggested:

> I don't know how the logistics would work for this, or if teachers would actually be up for this, but whenever [facilitator] talks about how her class goes and how she approaches it, I always feel very interested to see that. So, if there was a way for us to take her class, I don't know if we could get credits for PD that way, or if it's paid for by the program, or the timing and stuff, but to actually see it implemented by [facilitator]. And although it's not high school students doing it, it's early engineering, so they were recently in high school for a lot of them. Just seeing kids introduced to it would be helpful for us. It would give us more of our own engineering knowledge because we were taking the class. Plus we could be watching with a keen eye to see how she's teaching it.

In the second focus group, another person sparked a similar discussion in stating:

> Another thing that I really wanted to do is, because we don't have that engineering background, if there was some kind of class or during the summer or PD thing that we could do where we could learn the basic things that we should know so we are teaching it correctly. That's my one thing that I don't feel comfortable with.

Overall, teachers felt that taking an engineering course would simultaneously help them learn how to teach the EDP and increase their own content knowledge.

In talking through the feasibility of an engineering class, one teacher described how they were able to observe a video of an engineering class as well as work with engineering students. However, upon further discussion, the group agreed that taking a class with other students would be far superior to watching a video, observing a class, or participating in an online training. One person reflected, "If I took the class, it would force myself to learn it better because I'd have to turn in a project or turn in a paper… That would be a lot more effective if I took the class." Another person added, "I think that the online idea is not as helpful as in class, in-person, just because being in person, in her class, we would have two benefits: we would be learning more about the process plus we would get to learn about her teaching and how students are reacting." A third teacher remarked that it would be good to see how students were graded at a college level to inform their rubrics.

Several individuals reiterated that it would be good to offer PD credit for participation. Conversely, in another focus group, one teacher suggested that participants be able to take

the course as a student, such that creating a portfolio for PD credit could be optional. She explained,

> I feel like what stops teachers from going through and actually using the curriculum or online course the way it should be is that I need to think about implementing this in the classroom and gathering evidence. I would like to just have time to just process it without having to think about how, right then and there, how I'm going to apply in in my classroom and make lesson plans.

Others agreed that it would be good if an engineering course could be optional for those interested in participating. However, in these two focus groups, the level of excitement seemed very high.

Sharing and Learning from Peers. Teachers in the second focus group spent some time talking about how they would like to see how other teachers in the project were applying the EDP to their content areas and how their units were being implemented. As one teacher initiated, "One thing that I would like to see from them is, I would like to see how [teacher] taught one of these things. Right? I mean we all committed, our administrators are committed. What does that look like?" Everyone in this focus group agreed that they would like time to hear from other teachers while developing their units. As one person extrapolated, "When you can see someone, it's like 'hey we all watched the same thing,' but this is what you did with it, [and] this is what I did with it. I think that becomes a lot more powerful." Another person suggested that each person share their lesson plans and one video to preserve the time allotted to the professional development sessions. This person was excited about creating an online professional learning community, which might be important since some teachers are from another island. This individual suggested,

> I like the activities that we are doing during the [professional development sessions]. It could even be that we just upload the videos. I don't necessarily need to see [teacher] in *this* time to share, but if I could go online to see that... it creates that optional space. Just kind of that repository, like those gold standard lessons... that dumping ground that I can see what other teachers are doing that creates this virtual community. It might keep us more connected because it's a valuable resource so we are opting in to thinking about the project more.

Other Suggestions. This theme encompasses two other suggestions were made in different focus groups. One person requested having the engineers who work with the project provide feedback on the teacher-developed STEM units. This person commented, "I'd like for the engineers to look at the [unit plans]. I know we have that time where we can ask them questions, but I'd just like to see if the units that we are actually creating are meeting the standards they would want for the engineering program." Others agreed and this person went on to specify, "Any engineer that's related to the program, just look at [unit plan] and say, hey, you need to change this or to make this more rigorous, you should add that... and tell me things that because I don't have the experience, I would not know." In another focus group, one person wished that they could continue to ask questions and receive feedback on their lesson plans during the summer, especially for those who are gearing up to teach engineering pathway courses next year.

Benefits of Teacher-Developing STEM Curriculum Units

Teacher-Developed Units are Meaningful and Motivating. When asked to consider whether there was any value in having teachers develop their own STEM curriculum units incorporating the EDP, most comments related to the perception that teacher-created curriculum is more personalized, meaningful, and motivating to use. As one participant shared,

> The value in creating your own units is that it's what you are already doing in your classroom, things that are relevant to the way you teach, that you know that you are comfortable teaching, and it's not an adopted curriculum. So that makes it very relevant to yourself and with that, you'll invest the time that it takes to do a good job at it and that's meaningful to yourself.

A second person in the same group agreed and further explained,

> If you are creating your own units, you are going to implement it in the classroom… There are going to be certain units that you really have a tie to. Let's say there's a need in the community for something, in your personal community, you want to focus on… you can create the units for it. So I think that's very important and very useful to have.

In another focus group, one teacher described the feeling of creating a unit, implementing it with students, and "going through it the first time and just rocking it!" This feeling of success was motivating for that teacher to continue to use that unit again and again.

Teacher-Developed Units Address Content and Standards. The second theme that emerged had to do with being able to apply the EDP to their particular content area. One teacher said, "The value of developing my own units is that I can tailor it to the content. That's still really difficult, and I see that we'll get to that later. But that was the most valuable that I found." Another teacher built on this idea by adding that it helped him develop his own content area knowledge. This person shared,

> The best thing I liked about developing my own unit was I had to learn the content better and it forced me to because… I never write out a unit this detailed. So when we got to turn in these detailed units, it forces me to learn everything a lot better and actually do a lot more research and tie it to the appropriate standards. So I do a lot more in-depth research on my content.

A third teacher described how units will address the standards and fit better within the communities and context of the state of Hawaii. Another teacher looked forward to being able to apply the EDP in a way that deeply attaches to the content and bridges with other standards and benchmarks. Last, one person mentioned the benefits of sharing and using the lessons other teachers created, as well as getting personalized feedback and graphic organizers to support teaching the EDP to students. These benefits represent some of the strengths of relying on teacher-created, versus one-size-fits-all types of curriculum to teach the EDP.

Integration of the EDP into Course Content

Teachers were asked to consider aspects of the EDP that are relatively easy to integrate into the content they teach and aspects that they foresee as challenging. As in previous sections,

the questions were designed to keep groups thinking in ways that were solution-focused by asking participants to come up with some suggestions or supports that would address those challenges.

Aspects of the EDP that are Easy to Integrate. In both focus groups, the only individuals who reported that the EDP was easy to integrate were those who were currently teaching engineering courses. As one person joked, "My class is engineering, so it's not an 'integrate'. I mean I teach it." This comment motivated another to explain, "I agree that in this day and age, it is very difficult to put [the EDP] into an existing course, which is why I'm so glad I'll be teaching an engineering course which is designed to just teach this." All teachers in this focus group agreed that it would be helpful to implement the EDP in an engineering course where teachers could spend a whole year creating engineering design challenges to meet those standards. This finding provides some support for the shift in the ESS project and the creation of the K-16 Pipeline which will focus on getting Engineering I and Engineering II courses established in the HIDOE. In the first focus group, one person added that of the sciences, biology might be the easiest to integrate the EDP into because it aligns with the scientific inquiry process.

Challenges and Suggested Supports for EDP Integration. Teachers in both focus groups iterated the same two challenges, which were very much related. First, teachers explained that the HIDOE shift to the SBAC and end-of-course exams has placed a lot of pressure on teachers to cover necessary content during the year. One teacher lamented that her biggest challenge was "the fact that we have end of course exams. So dedicating time to teach a new process that is not on the end of course exam is frowned upon at many levels within the school and within the state and country." In another focus group, a teacher extrapolated,

> I would say that one of my challenges with the whole engineering design process is as a math teacher, I'm pigeon holed into teaching for the SBAC and all these tests. I'm having a hard time finishing my curriculum... I just feel like I'm getting all this pressure. We have all these test dates. We have to go practice in the library. That's my biggest challenge. I'm having a hard time figuring out how I'm going to fit it in.

Another math teacher chimed in, "But I think it's hard for math because we have to fit everything in that year and they don't leave any free days to do anything. You are just like always teaching something."

The second theme relates to the first and encompasses comments about needing EDP projects that teach complex concepts that are required in their content area. As one teacher in the first group asserted, "How do I put math in the EDP... math is project resistant because you can't put enough complicated math [in it]." Similarly, another math teacher in the secondd group stated, "I think one of the challenges is trying to fit all of the curriculum and integrate the lesson into the most applicable spot… It's valuable that I created [STEM unit] and maybe it's just me not having an engineering brain, but, where am I going to fit this math into this?" Other science teachers had similar responses as the following:

> We are studying universal gravitation now and that's a lab and there is a lab that you do to test that, and you can solve for g or whatever, but that's not the engineering design process. That's two separate things. I think certain content applies itself well to EDP, but

> not everything has to be EDP linked to content. Because there's EDP, inquiry, and experimental design and they are not all the same thing.

It seemed that because teachers feel strapped for time, they really need support to assure that an EDP unit covers the breadth of content to the depth that is needed to justify the instructional time it takes to implement a project with students. To address these concerns, teachers proposed two suggestions that may help to mediate this issue.

Providing Ideas for Teaching Complex Math and Science Concepts through EDP. Teachers in both groups requested some guidance to help them use the EDP to cover required content in ways that complement engineering. As one teacher remarked, "What I'm wondering is what does engineering algebra look like? It's showing the relevance in mathematics. What does engineering physics look like? Here's what we can do in Physics and chemistry as integrated engineering sciences." Another teacher built on this idea and suggested, "I think what would be awesome is if there was more of what [teacher] was talking about earlier... This is what I can do in geometry for engineering or this is what I can do in geometry that will relate to physics that will relate to engineering." A third teacher then detailed:

> What we need to do is get that hard core stuff and teach [students] how to apply it... Can we go into that hard math class and say hey, we're going to do this really interesting thing with trigonometric things and let's look at tension forces on bridges and let's actually calculate the force on every beam on a bridge and then let's look at the material science of why we need to put on this particular beam, a different type of alloy. That's high school level engineering that I think our schools have the capacity to do and that's what I'm hoping we can develop.

Another teacher reiterated that it would be useful to have an opportunity to hear from other participating teachers in their content area.

Using Engineering Courses to Apply the EDP to Other Content Areas. In the first focus group, one teacher put forward a thought that others agreed with. He stated,

> I think the real strength of having the engineering course separate is if I get to meet with [teachers] then I can take a chemistry project – like some chemical engineering project, and do that in my [class] because she isn't going to have the time. I can do some bio-engineering stuff in the engineering stuff. I can go and take all these projects, and run them in my [class] and then all the kids will love my class. This is what we do in chemical engineering. This is how you get chocolate to stick to cookies.

All joking aside, this kind of collaboration requires time for teachers to meet. As one teacher in different group replied,

> I would like to try to figure out a way to collaborate more with the science teachers and the math teachers. When my kids have an engineering problem, I'm like well go ask this teacher how they would do it... That would be a great resource for the kids to be able to ask those kinds of questions.

In the first group, one teacher described how their school requires them to collaborate on units that focus on the EDP. This person explained, "We are talking about help with the EDP, and

one of the most helpful suggestions that [Project Director] made for us was to center ourselves around the engineering teacher. When I read [teacher's] lesson, I can see where my [content] goes in there and that was really helpful." This approach helped to reduce the time needed to incorporate the EDP into other content areas, and focus on complementing the EDP projects implemented in the engineering course with applicable content in their class.

Implementation of a College-Focused Engineering Pathway Program

The Project Director for the ESS and K-16 Pipeline projects specifically requested information to inform the implementation of the Engineering I and II courses, and the establishment of a college-focused engineering pathway program within the HIDOE. Therefore, teachers were asked to really think about what an engineering pathway program would look like and what suggestions they might make to help assure that it is successful. Their recommendations fell into three main areas: curricular relevance and rigor of college-level engineering courses and STEM careers, school-level supports for planning and collaboration, and formalized HIDOE system-level backing for the initiative.

Ensuring Rigor to Prepare Students for College and STEM Careers. One focus group had a lengthy discussion about what it means to prepare students so that they can succeed in introductory college-level engineering courses and technical careers. Their biggest concern was that the rigor and relevance of their STEM curriculum units would not match the expectations for college and careers. As one individual articulated, "The engineering design process is one component of engineering, but maybe not the biggest component because you have to have all these technical math skills and technical trade skills... When you look at the whole scope of engineering, there is high level math, there is physics, there's electronics." Another teacher shared her experience entering college in stating,

> I went to a really traditional high school [before] I went into chemical engineering my freshman year and I felt like I went in super unprepared. And my first year they were like you are going to make a solar water heater… They told us here are the materials. Here is the heat transfer... What I did my freshman year of college, I think we should be doing in high school. Build this, here are all the properties of this metal and whoever produces the hottest water coming out of this pipe wins the competition. Like that versus I'm going to put pennies on a bridge, whose is going to hold the most pennies.

A couple of people felt that students need opportunities to gain more technical skills before entering college, like soldering and fabricating prototypes, while others felt that students need more data analysis skills. Another person mentioned that students need to build communication skills.

The differences in opinions led this group to the realization that they need to be better oriented to expectations from colleges and potential employers. As one person asked, "What's happening in the college and industry expectations?" Another person added,

> This comes back to what's happening at college and what are our kids lacking? I love that [idea] because I went into engineering in college too and I wasn't prepared. I think that's a great idea and [facilitator] has been kind of telling us what she's doing in her [college-level] classes, but maybe more fully finding that out.

Assuring that Schools Provide Support for Teacher Planning and Collaboration. Teachers in both focus groups agreed that they need their schools to provide some planning time for planning and collaboration beyond the life of the project. As one person articulated, "What would be good is if we had an extra prep [time] at school. If you had an extra empty period, it would just make this so much better because you could just plan the whole thing all year long. That would be optimal." This suggestions arose in response to two different concerns. For some teachers, they are concerned that they won't have adequate time to prepare to implement new STEM programs or Academies next year. One teacher asserted,

> Especially when you're preparing to implement it as a new academy or new program at the school. We are implementing this next year and we don't work together on any of this except when we are at these workshops. So, taking something that's accredited by the university, and we're just kind of throwing it into next year, feels a little crazy.

A second person in the same focus group explained,

> I don't need one hour a day or something like that, but I need time to read through [teacher's] lesson and see what he's doing because it's getting more and more complicated. He's doing more real life problems, so I have to think more about what to do with his problems and often times I can't. I also need more practice with the Next generation Science Standards… I'd better look at these standards, and then low and behold I forget the English one. It's like, I did the science one, didn't do a language arts one. There's a lot that goes into this lesson, to make it a complete lesson. So just more time to do the things that I need to do too, like become more familiar with the next generation standards.

A teacher at another school observed some overlap between the projects included in the Engineering I curriculum and those taught by IET teachers and others who are trying to incorporate more problem-based learning into their content. This person put forth, "Articulation between us, for our school, and the teachers who are teaching [ROV and robotics]. That would be good." This person went on to suggest that, "I think for the project it would be good to have extension problems or extension [foci]. You know, if you wanted to go farther you could to this. I think that would help with the rigor of the activity if it's something that the kids have already seen before."

Eliciting State-Level HIDOE Support for an Engineering Pathway Program. A few teachers shared concerns that the HIDOE needs to commit to the program and that current STEM initiatives are too splintered across the state to gain traction. As one teacher revealed,

> At least at my school, I'm pretty concerned about what is that high level commitment to it? Because everyone's principal signed off on it, but where is [Assistant Superintendent] and [Superintendent] and the complex area superintendents because there is about to be a lot of other initiatives. I'm a little concerned that some of the supports won't be there in the long run if this doesn't get formalized into some DOE structures. I think that keeps back a subset of investment of other faculty members from the schools that aren't here.

Another comment spoke to a need for the HIDOE to combine different STEM initiatives to have the greatest impact. This person shared that,

> There are so many things going on in the state with STEM and everyone thinks that their thing is the thing and they have to find a way to combine… How do we look at STEM outside of robotics and all these other [initiatives]? Finding a way to orient all of those different and divergent directions in STEM for the state would be so valuable for our schools and our students and for my personal sanity.

In terms of the schools that plan to implement next year, a third person pointed out that schools have different plans for what participation will look like and teachers are at varying levels of experience and knowledge. This person would like to see this project formalized across the state in ways that take into account various plans for pathway programs and course scheduling, as well as different levels of instructional ability and rigor. This person went on to state that,

> Once you've exposed the engineering design process for so long with all these different schools, you're going to want to start to tier it… So there's some pieces in front that need to be addressed so that the teachers that are in the project are comfortable at the time. There needs to be that buy-in of some type from the schools… [Project Director] knows how to continue to grow this project because I think it's awesome.

Summary of Key Points

- Teachers shared positive perceptions of their experience with the EDP such as engaging students in hands-on activities, solving authentic real-world problems, and focusing on improvement.
- Several teachers in the first focus group reported feeling comfortable and confident with certain aspects of the EDP due to implementation in Years 1 and 2 of the ESS.
- Teachers had lower levels of confidence with teaching students how to improve their designs, how to value the Gantt and Pugh charts to organize their progress, and how to manage their instructional time to address all steps of the EDP within the time allotted for a design challenge.
- Teachers reported that the most valuable aspects of the project were the work sessions which provided opportunities to go through design challenges, the substitute days to design STEM curriculum units with their peers, the feedback and resources to improve their units and opportunities to collaborate and learn from more-experienced peers.
- The benefits of having teachers design their own curriculum units were that teachers perceived them to be more relevant, meaningful and motivating to implement.
- Teachers that teach engineering-related courses reported that the EDP was easy to integrate and were excited to teach the content.

Recommendations

Formative evaluation findings are a method for gathering recommendations for project improvement. That being said, project implementation requires balancing recommendations with what is feasible for the project. This summary of recommendations made by teachers is meant to inform the ESS and K-16 Pipeline projects as they move forward.

- Teacher understanding and confidence with the EDP could be enhanced by dedicating time during the professional development sessions to go through each EDP step.
- Teacher confidence teaching the EDP could be improved by providing teachers with tips for time management and lessons learned to help them prioritize steps of the EDP.
- Focus group participants agreed that an introductory college-level engineering course and opportunities to share and learn from their peers would provide opportunities to observe how to teach the EDP and increase their engineering content knowledge.
- Suggestions to facilitate the integration of the EDP into other content areas included providing a list of ideas to teach complex math and science concepts, and utilizing engineering course projects as the basis for integrating other supporting content areas.
- Teachers proposed some suggestions to strengthen the implementation of an engineering pathway that included curricular supports to assure rigor and relevance, school supports for teacher planning, and system supports to establish the program.

Engineering Success in STEM (ESS) and the K-16 Engineering Pipeline
Teacher Focus Group Report
End of Year 3
June 1, 2016

Overview

School year 2015-2016 marks the conclusion of two concurrent and connected professional development projects developed by Chaminade University and funded by the Office of Naval Research: the Engineering Success in STEM (ESS) and the K-16 Engineering Pipeline: Engineering Success in STEM (K-16). The ESS project is in the final year of a three-year grant that provides professional development to Hawai'i Department of Education (HIDOE) public school teachers to facilitate the development and implementation of rigorous curriculum units that engage students in the engineering design process (EDP) through science, technology, engineering, and math (STEM) content areas. The second K-16 project provides additional supports in the final year of the ESS through process objectives that establish an engineering pathway between the HIDOE and the University of Hawai'i at Mānoa College of Engineering (UHM). The objectives for both projects are listed in Table 1.

Table 1. Objectives of the ESS and K-16.

Engineering Success in STEM	K-16 Engineering Pipeline
1. Develop a deep understanding of the engineering design process (EDP)	1. Define the requirements for the Engineering Pathway between HIDOE and UHM
2. Introduce teachers to the Engineering I and Engineering II curriculum map	2. Develop and pilot test the teacher training session curriculum
3. Facilitate the collaborative development of rigorous engineering pathway units based on the curriculum map	3. Involve teachers in collaborative development of rigorous engineering-focused units
	4. Increase the number of high schools offering the Engineering Pathway core courses
	5. Identify and develop additional engineering-related training sessions needed by teachers
	6. Develop an agreement between the HIDOE and UHM College of Engineering that specifies the outcome of students who met the college requirements

In Year 3, the ESS project shifted the focus from middle and high school teachers in one HIDOE complex area to high school teachers in six complex areas. This change was perceived as critical in helping the HIDOE institutionalize an engineering pathway. In total, six public high schools participated: Kaimuki High School was in its third year of participation through the ESS and five others were in their first year with the ESS and K-16 projects (Castle, Kealakehe, Leilehua, Moanalua, and Pearl City high schools). Participants included 15 math, science, engineering, career and technical education (CTE), industrial and engineering

technology (IET), and STEM resource teachers. Twelve of these teachers (80%) were new to the project in school year 2015-2016. As such, the project team made adjustments to the content of the professional development sessions and the participation requirements.

Teachers received a comprehensive system of professional development supports through the ESS and K-16 which included training and mentorship during professional development sessions (7 sessions/year), teacher-directed work days to collaborate with peers on STEM curriculum units and projects (2 substitute days/year), and consultation with engineering and instructional mentors (as requested). Requirements for participation were adjusted mid-year based on the amount of material to cover during the professional development sessions and feedback from teacher participants. By the end of the school year 2015-2016, teachers were expected to: 1) develop one STEM curriculum unit in collaboration with teachers in the same content area from other schools (ESS Objective 3), and 2) complete a collaborative project to align a unit included in the Engineering the Future curriculum with the Common Core and Next Generation Science Standards (K-16 Objective 3).

An external evaluator was contracted to conduct a formative and summative evaluation of the project. The evaluation was stakeholder based, improvement oriented, and focused on progress toward meeting the stated goals and objectives of the ESS and K-16 projects. Focus groups are one method for collecting evidence of the implementation and effectiveness of professional development supports from the perspective of participating teachers. Focus groups took place at the mid and end points of each year to gather information that the Project Director could use to guide program improvement and future project planning. This report summarizes the findings of end-of-year focus groups that relate to ESS Objectives 1-3; and K-16 Objectives 2-5 (see Table 1). Specifically, the project was interested in gaining information about teachers':

1. Understanding, interest and confidence in teaching the EDP
2. Experiences developing and implementing STEM curriculum units
3. Perceptions about the value of the Engineering the Future collaborative project
4. Insights into what aspects of the professional development sessions were most valuable and areas to strengthen
5. Plans for implementation of the Engineering I and II courses
6. Comfort and confidence teaching the Engineering I and II courses
7. Perceptions about the college-focused engineering pathway program, potential challenges and suggestions to address those challenges

Methods

End-of-year focus groups took place during the last of seven professional development sessions for school year 2015-2016. All 15 teachers participated in one of two scheduled focus groups. Groups were structured so that teachers from the same school remained together because they may have similar experiences with training, curriculum design, EDP integration, and implementation. Additionally, two schools that were either currently or planning to implement a STEM Academy for students were also grouped together. The first focus group included seven teachers from two high schools, and the second had eight teachers from the remaining four high schools.

Focus groups were held in a private room and facilitated by the external evaluator. Participants had an opportunity to discuss nine open-ended questions or pass if they had nothing to share. The facilitator briefly summarized responses and asked for additional thoughts or clarification before moving to the next question. All focus groups were transcribed verbatim and analyzed qualitatively by coding participant responses into emergent themes and quantifying the frequency of those themes within and between focus groups.

Results

The findings included in this report are based on the experiences of high school teachers participating in the ESS and K-16 projects. Therefore, it is important to keep in mind that teachers' experiences with the projects are also a direct reflection of the schools, communities, and contexts within which they work. Participating high schools were involved in different school specific initiatives, such as STEM Academies, Instructional and Engineering Technology (IET) pathways, and competency-based course schedules which group multiple competency levels together within a content area (i.e. algebra, calculus, and trigonometry students in the same course). One school was in a community where teachers reported high levels of student engagement in an afterschool robotics program and aspirations for attending Ivy League colleges on the mainland. The HIDOE has other system level initiatives which also affected teachers' experiences with the project, including the implementation of the Standards Based Assessment Consortium (SBAC) standardized test, end of course exams, and mandatory training on project-based learning (PBL). Last, teachers participated in the project for different lengths of time (Kaimuki teachers had three years with the ESS, and 12 others had only one year) and came with varying levels of prior experience with engineering education and the design process. The above information is intended to explain the circumstances that may contribute to these findings.

Teacher Understanding and Confidence Teaching the EDP

The ESS project specifically aimed to increase teachers' knowledge of the design process and confidence in developing and implementing engineering-focused units (see Table 1, ESS Objectives 1 and 2). To examine this desired outcome, teachers were asked to consider how participation affected their interest or confidence in teaching the EDP, their integration of engineering design into STEM content areas, and/or their approach to teaching. They were also prompted to consider which aspects of the project brought about these changes.

Increased Teacher Confidence. The large majority of teachers in both focus groups reported that their participation in the ESS and K-16 projects increased their confidence with the EDP. Responses fell into four major themes. The largest proportion of teacher responses reflected confidence gains due to exposure to the EDP through work sessions and curriculum resources. As one teacher shared, "

> I just appreciate the fact that there were so many practical tools that I was able to get from this program, like the rubrics and the projects. I have integrated so many of the materials and the tools that I have gotten from this into the program. I have increased

> my confidence in teaching because of all the tools that I've received. That's been a really great thing that's happened to me with this program.

The teachers who shared this perspective tended to be new to the project in school year 2015-2016 and had little prior experience with the EDP. Another teacher commented,

> I have a science background and so not so much engineering, and I think the resources that they gave us and all of the books… *Thinking like an engineer* - There's a lot of content in there that I like because I think that's the part that I need to strengthen if I want to teach this class. So I think the resources that they have given us are super helpful and that has also increased my interest and confidence in teaching the EDP.

A few individuals also communicated that they were excited to engage students in the EDP next year, as illustrated in the following comment:

> So I wasn't really aware of the engineering design process before this. So this is me being very much aware. And I didn't get to implement what we're doing here much this year because I'm not teaching classes that are related to that this year. But I'm so excited about being able to do this next year. And it will certainly be a different class than I've gotten to teach in the past. I feel that this will be a great chance to help those children learn to think

The second major theme had to do with confidence gained through actual implementation of the EDP. About half of these teachers had been with the project for multiple years. As one person discussed,

> I've been using the EDP now for 2 years, so I'm pretty confident with it. I think my students, especially in Engineering II, are pretty confident with it. And even my Engineering I [students] because we teach the EDP in all our classes - science, math, engineering, English… That repetition has helped our students gain a better understanding of it.

Another individual remarked that their confidence increased because they were able to design and implement a unit that integrated the EDP within their own content area. This individual pointed out that,

> When we first started three years ago, our first EDP project was in our own content area... which I still use to this day… I really liked that because when you first start this thing you don't know how integrated it's going to be and you want to find confidence in your own subject matter.

Two other teachers reported that their confidence increased because they were able to go through the EDP during the design challenge activities embedded in each work session. One person mentioned that the project:

> Definitely helped to build a lot of confidence in myself. [It was] a good refresher in the engineering design process, but really getting my hands into some of these different projects that I haven't done before gives me the confidence to try it out with the kids.

> And if they don't do so well, it's ok. I can always improve on that... So just doing the basic projects [gave me] a lot more confidence to do these things.

The third major theme included comments that looked beyond these projects and made connections with other HIDOE initiatives. Three individuals talked about how their experiences in the project increased their confidence with problem-based learning (PBL). As one person declared, "The other thing that I felt confident about was we just had a 3-day workshop doing the PBL and the PBL is exactly the same as the EDP and I sat there for 3 days saying this is the same thing. There is definite alignment." A second teacher agreed and stated, "It's very similar to the EDP... The other teachers were kind of struggling, but we shouldn't have been there unless we were there to assist other teachers... The EDP is the process that I'm going to follow, even when we do our PBLs." Two other teachers shared that their participation bolstered their confidence with the Next Generation Science Standards (NGSS). One of these participants said, "As we move towards NGSS, EDP fits better with NGSS rather than content... It seems more doable... It might be an easier way to address the NGSS standards through the EDP."

Finally, the fourth major theme centered around teachers' desire to increase their confidence with engineering content. One focus group participant put forth, "Could we build our confidence together as a cohort in some of the higher level training stuff, particularly in the math and the technical aspects of engineering... That's where I'd like for my confidence grow is in more the technical engineering." Four other teachers agreed and acknowledged that they planned to take the summer engineering course offered through UHM and sponsored by the ESS and K-12 projects to increase their engineering content knowledge.

Enhanced Approaches to Teaching. Three themes emerged from teachers' reflections on whether participation in the ESS and K-12 changed their approach to teaching. First, individuals in both focus groups mentioned greater collaboration and integration between different content areas. As one respondent stated, "Coming from a math background, it kind of opened my eyes to see how math relates to the STEM Academy and how we are going to try to approach creating pathways at our school... I notice how I'm trying to incorporate using that math skill into other things." Another individual shared, "When you're going through the actual books, it was nice to see that it's not just like I'm going to my math class, I'm going to my engineering class... It incorporates all different kinds of math in engineering, versus going from one class to another. It's all intertwined."

In the second theme, both focus groups discussed plans to be more project based through the EDP. One of these teachers mused, "The whole idea of having everything centered around projects... Now we are actually doing [EDP] and making it fun and doing physical things. I'm going to have a good time."

Last, for a few science and math teachers, participation in this project helped them to realize that they prefer to support EDP implementation in the engineering course with related curriculum in their content area. One person admitted,

> I don't feel like it is something I would center any of my lessons around. I feel like the content is important for parts of the EDP... I think it's great for us to attach ourselves to [teacher] and help support that project, but I don't think it's been useful to bring the

> entire process into my classroom… I'm still in the mindset where I want to focus on the content and how that can help support a bigger project, like in [engineering] class, instead of do the whole project in my class.

To some extent, this perception was influenced by the amount of time it takes to implement the EDP in class. As another teacher in the same focus group agreed, "I understand what you're saying because that [STEM unit] normally takes 1 and a half weeks to 2 weeks and it takes twice the amount of time now because of the EDP."

Deepened Understanding of the EDP. Several teachers reported that project participation enhanced their understanding of the EDP. Two teachers that were in their first year with the projects talked about being able to see connections between the EDP, the IET design process, design thinking, and/or the scientific inquiry process. As one person stated, "I guess adapting the IET design process… there are several steps or more steps than the engineering process, but to show [students] both of them [so] they can see the step by step process in the beginning of the design and then use the engineering design process." Two others shared that they understood how the EDP could be used as a problem-solving process for any situation. One individual mentioned, "Listening to how our English teacher applied [the EDP] to making a video, and our social studies teacher applied it to finding a prom date… it helped me to think more creatively about what I can use it for and it makes a lot more sense to me now." One person also shared that they could better understand how their content area fits with the EDP.

Project Supports that Contributed to Teacher Changes. Teachers were prompted to consider what aspects of the project brought about changes in their confidence, understanding and teaching practice. A number of people reported that the work sessions, curriculum and resources had the greatest impact on their understanding and confidence with the EDP. As one teacher noted that, "Having these classes and workshops helps to give us more material and different ways to teach the EDP, so it's been very helpful." With equal frequency, teachers discussed the value of collaborating with other teachers, receiving feedback from peers, and sharing ideas. In the second focus group one person stated,

> Another thing that was good is that we could talk to each other… that also helps us to try to plan for what we want to do in our classrooms. Besides just the resources they give us… networking because I think other schools are farther along in this engineering pathway thing than we were.

Last, several participants in one focus group concurred that the most impactful aspect of these projects was the level of support offered by the Project Director and staff. One teacher put forth,

> It was a super supportive and a very quick and responsive program. You could tell that the people involved have been teachers and haven't forgotten that. I mean it's usually [Project Director] that we're contacting, but even everyone else that we've ever had to contact, they really take our job in to consideration and try to make things easier rather than just giving us stuff to do.

Another teacher agreed and further explained,

> I concur with [teacher] that this grant has given us everything we needed to get going. It got us to the point to where we're at and when we do need support, it's always there – especially [Project Director]. When she says she's going to get something done, it's done. And that's what I really respect about her and about this grant. Things are done when they are supposed to be done.

Experiences Working Collaboratively on STEM curriculum units

Teachers were asked to consider their experiences working collaboratively with teachers from different schools and/or content areas to develop STEM curriculum units and complete the Engineering the Future group project. The Engineering the Future project entailed aligning Common Core and Next Generation Science Standards (NGSS) with a unit included in the Engineering the Future instructional materials created by the Museum of Science. In each focus group discussion, participants were encouraged to consider aspects that were positive as well as suggestions to strengthen future projects.

STEM Curriculum Unit Development. Collaborative unit development took place in the first semester of school year 2015-2016. Participating teachers provided some feedback about their experiences in the mid-year focus groups, however they were asked to consider their experiences again as the projects come to a close (see ESS Mid-Year Focus Group Report for more information). During the end-of-year focus groups, the theme that came up with the greatest frequency had to do with being able to work with other teachers who teach the same content area. In one focus group, an individual described,

> It was very nice meeting teachers from other schools and then just having the same goal in mind... And especially in science, because usually there's only one chemistry teacher or one physics teacher and you don't get to talk to other teachers of that specific content… at least if there's another teacher of that content, you feel a little bit more validated in what you're doing and I think that's important.

A second person agreed and added, "I like it because you get varying levels of expertise on certain topics and also you get someone else looking up standards… Some people are really good at it and some people are not, like me… when somebody else can help me look up appropriate standards, it's always helpful."

With second greatest frequency, teachers reported appreciating the feedback they received from their peers and having critical friends to help them improve their units. This theme also came up in the mid-year focus groups. As one focus group respondent detailed,

> It was nice to get feedback from people from other schools, who I didn't know anything about, who had then comments on how to do it [and] who also had a similar interest in what I had been doing… You get a much broader response base for opinions. It's not just people who are close to home or who know you so they're not going to say one thing or the other. So you can really trust that they're being objective.

Teachers also mentioned that it would be helpful to have these types of peer interactions throughout the year and a third person stressed the importance of professional learning communities in developing teacher confidence. This person shared, "I feel like seeing that

perspective and how everyone else was approaching it, gives me part of that confidence I need."

Another theme that echoed the results from the mid-year was the importance of hearing from other teachers who had more experience with the project. Specifically, teachers reported that it was valuable learning about the experiences of those who had implemented the EDP with students in Years 1 and 2 of the ESS project. One person commented, "Some of the positive aspects was seeing programs that have the experience of doing it and actually teaching this class. I thought that was very valuable." In another focus group, a participant shared, "I'd have to agree that getting together with Kaimuki and [the] other schools allowed me to see their experience or hear their experience and be able to adapt it to what I would like to teach."

Last, the participants from Kaimuki had worked with teachers in other content areas at their school in Years 1 and 2 of the ESS. These individuals reported that the experience was beneficial because it helped them to plan for integration, consider supporting content that could be taught in other classes, and support each other with EDP implementation. One of these teachers stated, "One of the nice things about collaboration is you have to consider where everyone else is. So often times, chemistry is an out person. But, I couldn't do a certain project if I didn't have the chemistry person working with me." Another individual further explained,

> The math department doesn't realize it, but they help me out with the geometry and I'm able to explain a little bit to the kids about why they're building the structure... The science, they don't realize what they're doing for me is they're going extensively into the force... but it allows me to at least reinforce what they've learned inside of the engineering. So, it helps.

Engineering the Future Standards Alignment. In the second semester of school year 2015-2016, teachers worked together to identify standards that were addressed through projects included in the Engineering the Future instructional materials. This project served several purposes. First, it provided an opportunity for teachers to get acquainted with one curriculum unit and see how it could be used as a supplemental resource to teach the standards next year. Second, teachers shared their projects with one another in order to get through more material as a group.

When discussing the Engineering the Future collaborative project, teachers in one focus group talked about three benefits of this assignment. Most frequently, teachers reported that the project was valuable because they were able to identify the learning standards that aligned with projects they might implement next school year. Several participants agreed that this was important for accountability purposes. One of these individuals mentioned, "I think it's good for standards. If admin comes and questions what you're doing, all the standards are aligned. So, I'm looking at it from that perspective. I think it was good."

Teachers also shared that the Engineering the Future instructional materials were a good supplemental resource to teach the engineering design process next year. As one person put forth, "It's a supplemental resource that you can use and you can gain some projects out of and gain some lessons out of. You can pick and choose." Last, two people shared that the Engineering the Future project helped strengthen their knowledge about the

standards or awareness of standards for other content areas. One participant voiced, "I did not feel confident in the language arts standards, so we brought in someone. So it just makes it a little easier. But at least if we were ever challenged about it, then here are our standards and everything." The second person agreed and added, "I think it was also helpful because it just helps you to think about [the standards] from a different point of view and you should always observe it from different points of view and then you learn it better - you remember it better."

Conversely, one focus group spent a lot of time discussing some confusion with the intended use of the Engineering the Future curriculum. Teachers reported that the text book and work books did not align, which resulted in some teachers perceiving the curriculum as not useful and others thinking that they were two totally separate resources. This is illustrated by the following conversation:

Teacher 1: The text book and the work books were not really closely aligned. They didn't really match up. I don't know if it was just a page number issue, but you would not know where to put that together.

Teacher 2: They are independent.

Teacher 3: But they are called the same thing?

Teacher 1: So that was not very clear to us.

Another teacher further explained that the project was frustrating due to this issue in stating:

> We were looking for alignment as we were going through and figuring out the standards and we were just like where is this coming from? What does this connect to? We kind of gave up on the textbook. By practical standards, we kind of just ditched it after a while and were looking at the workbook... We were hoping that there would be some alignment somewhere in there so that it was teaching content from the textbook.

Furthermore, teachers in one focus group were discouraged because the units were not already aligned with learning standards. As one person described,

> I'll admit that it felt a little frustrating that none of that was already in the text book. Usually in text books, they line up the standards already... Although it was pretty valuable, we weren't even looking at the whole textbook. We were just looking at one project and that was a whole day with 5 of us working. To approach a whole text book that way would probably not be very possible practically for teachers. And so that is one of the big downfalls of that textbook is it's not aligned or it doesn't show the alignment to anything. So, if I was handed that as a new teacher... that would add a pretty big challenge.

A second teacher agreed and added, "We still have to go through our standards, but I agree with [teacher], most textbooks come with all the standards aligned for you... It just made it one more step... It would be nice if it was already there and then we match it with [Common Core standards]." For many teachers, although the Engineering the Future project helped them to become familiar with the contents and align the projects to learning standards, further use of the curriculum materials may be limited for any units they were not able to cover.

Suggestions to Enhance Teacher Collaboration. As the focus groups progressed, teachers identified a few challenges to unit development and the Engineering the Future project. These are shared as a summary of the suggestions made to address each challenge. The purpose of this section is to provide the Project Director and funding agency with information to guide future program planning.

Have teachers design, implement, and share curriculum units. With greatest frequency, teachers in both focus groups suggested that future projects require teachers to develop, implement, improve and share their units. Teachers from Kaimuki were able to do this throughout their participation and reported that it was very valuable. As one person described,

> Three years ago, we had to plan [an EDP] in our own content area… I planned one and I implemented it, and you are going to learn so much from your own first EDP. I started going back to [Project Director] and saying, what is this problem statement? How is it different from the design challenge? You will learn more from actually doing one with kids.

New teachers similarly reported that it would have been useful to have them develop units in teams or individually in their own content area. A person in a different focus group explained,

> Some of the most valuable professional development activities and programs that I've done – The ones that I've felt the most confident in implementing and taking it on and felt really excited about trying it in my classroom, immediately if possible – Were the ones where I was invested in my own personal lesson plan in which I had guidance on, like from a mentor that has done this successfully, and also constantly meeting with the people that are teaching the same thing that I am so that we can look at the curriculum and see what ways we can approach certain skills in the process that I'm learning.

Furthermore, teachers in both groups stressed the importance of implementation and improvement. One person shared, "As a teacher learning in these workshops, you start to see different things about what makes your practice better so your opinions change along the way after you try something out." Another teacher agreed and put forth,

> What might have been helpful is to actually improve upon the units that were made [and] to allow the teachers to use those units or trade units… It's almost like you got feedback on the written piece, but when you actually do it the teachers might see that [it] doesn't really work... Putting effort into making the lesson was great, getting feedback was great, but we didn't get to try it in any way more than just I think you should add this.

Two others suggested that schools could share or trade units and provide the creators with feedback. Both individuals made suggestions similar to the following: "We could all look at each other's and take one and actually try to run that lesson or make the activity and see if it really works or not."

Assign the Engineering I teacher as the lead for unit development. Both focus groups arrived at the suggestion that collaborative unit development could center around the Engineering I course, with teachers from other content areas providing additional support. This

suggestion was based in part on the experiences of teachers that participated for three years. As one such person stated,

> I think what helped was if you have somebody who starts the unit... I think that's where we produced the best units... If we come up with a topic, and then I started the whole unit, and then I wanted math support or science support so then they could kind of just jump in and fill in their spots and then I could just tie it all together and see where I needed to have math, where I needed to have science.

Another teacher from this school concurred, "We liked having a point person." A new teacher in a different focus group came to a similar conclusion based on their groups' experiences this year. This person remarked, "It would be nice if someone taught an engineering class at our school and I kind of gave them the background on the math if we were all on the same page… I was nice going through [the EDP] and being like, oh, this is where math comes in."

Other teachers argued for a designating a point person at each school and providing some direction for unit development to get groups started. One example was the suggestion to provide participants with a list of potential topics that they could then adapt to fit their interests and communities. One person put forth,

> I think having a direction is easier. [Teacher] and I sat there for a really long time trying to figure out how to incorporate [the EDP] into the curriculum in chemistry. You don't want the kids to experiment with a chemical reaction. It was just really difficult to come up with the topic. So if someone [who] had a topic already could come to the table or a list of topics or something like that so teachers don't spend half a day trying to figure out what you what to do.

More experienced teachers agreed that it was difficult to come up with a topic in the first year, but that this got easier over time.

Provide time to collaborate in work sessions. A large proportion of comments were about needing dedicated time to work with teachers, especially those who teach at different schools or live on different islands. As one participant remarked, "I think one of the biggest challenges was the fact that we had people from multiple schools working together, but outside of the workshop time… And for us we had somebody from another island so there was no physical collaboration possible." In thinking how to address this challenge, one focus group got very deep into a discussion about having more time to work on unit development during the work sessions by eliminating some of the design challenges. As one person reinforced,

> As [teacher] mentioned, having work time built in. I personally feel that I would benefit more from having that work time with the group and maybe taking out one of the challenges because we did them every session and I don't know if we needed to do them every session. And so if you took one of those out and made that a work day or a work session for your collaboration, I think that would probably help eliminate the [challenges] without taking away from the other things we got.

Teachers also discussed a few other suggestions such as going through design challenges included in the curriculum, and providing time to collaborate across multiple meetings so teachers could prepare between work sessions. Another teacher explained,

> For the planning units together as groups, I think it's great if you start it in one session and you guys think about it and then you come back the next session and really work on it once everybody has a vague idea of what's going on. If you do it all in one then you barely have enough time to take all of your materials and get them all there.

Replicate the ESS model to develop deep understanding. All teachers in one focus group agreed that going through the design challenges was very valuable, however it would be worthwhile to have greater balance between experiencing the design process and having more time to develop their understanding of the discrete steps and design an EDP with other teachers. Five new teachers agreed that using the design challenges to focus in on certain steps of the EDP at the beginning of their participation would help teachers develop a deeper understanding of the EDP from the outset. As one individual mentioned, "I think either reduce the EDPs or as we did the EDP, focus on different aspects of it. So the first one we focus on just emphasizing Pugh or Gantt charts." Participants agreed that the design challenges were often too rushed and another person further explained,

> To reduce the time, we don't necessarily need to build the thing every single time for every project... If we're focusing on some of the steps, maybe we go all the way up to planning out the organizer, but not actually building the organizer... so that we're cutting down on time but putting more quality time into each of those sections.

From the evaluator's perspective, the teachers who had been with the ESS for three years were able to learn the EDP through a scaffolded approach that included work sessions that focused on each step of the EDP, dedicated time to design a unit with mentorship available if needed, and a final year that exposed them to many possible design challenges. This scaffolded approach seemed to fit teachers' needs and could be a model for future programs.

Create a mechanism to share resources beyond the project. The last suggestion was discussed extensively in one focus group and related to a need for a lending library. Teachers in this focus group felt that project kits and certain types of equipment are not used all year long and could be shared between schools. As one teacher pointed out,

> I think [the projects] focused on making sure that it's cheap, so that we all have access to [materials], but I think that if you want to increase the rigor, especially for Engineering II, all the teachers that are participating have to have access to the raspberry pie things and all of these electrical components and one of the reasons why we don't do that is because there might not be enough funding at the school. So while I think it is important for the Engineering I to focus on cheap things, I think that for Engineering II there has to be a lending bank or some kind of way for us to borrow materials so that we can implement those things.

A second person further explained,

> "If you want to go buy 20 raspberry pies and all the wiring and all the setup, that would be your entire $2500 that you got for your thing, but maybe you don't need that all year... If some of the stuff that we were using had those kits that then could be transferred and well packed up, I know that even on the neighbor islands, we would go and ship them back and forth. That would be a real good thing.

Several teachers agreed with this perspective and another added, "I think that the consumable part would be something that the school could pay for but for like the actual raspberry pie kits… like all of that… I can pay for batteries. I can use computers." A third person piped in, "That would be crazy good to have the opportunity to check that kind of stuff out."

During the course of the conversation, teachers agreed that lending libraries are one method for sharing resources, could be managed by one school, and may help to leverage resources and increase use. As one person revealed,

> We wouldn't want those kits to be wasted and just sitting there because I see that a lot… There are a whole bunch of probes just sitting there and the teacher doesn't use it anymore. That is so wasteful. I think if you could put it into the library, at least even if I can't use it, at least somebody else will have access to it. The STEM Pre-Academy at UH has a lending library, but it's limited for middle school and elementary, and O'ahu, but if you can have a high school based one... It's limited what stuff that they have.

A third individual stressed the importance of engaging teachers that use the library. This person suggested,

> And I just want to add, don't just give teachers stuff. Require them to do something with it. They will have a better experience with it and you'll get more back… Lend this stuff out and you have to record what you do with it… so now I can see how [teacher] used it… and now you start to see that you're building a network of collaborators.

Implementation of a College-Focused Engineering Pathway Program

The overarching goal of the ESS and K-16 projects was to develop and institutionalize a college-focused engineering pathway program that begins with the high school courses (including the Engineering I and Engineering II courses) and culminates in acceptance into the College of Engineering at the University of Hawai'i at Mānoa. As the projects near an end, teachers were asked to really think about their level of comfort and confidence with the Engineering I and II courses, how the engineering pathway program will look at their school, and any suggestions that might help to assure that it is successful.

Teacher Confidence with Engineering I and II. To examine the experiences of teachers as it related to their introduction to the Engineering I and II course curriculum (ESS Objective 2) and the content of the professional development sessions (K-16 Objective 2), teachers were to consider their comfort and confidence with the Engineering I and II curriculum. As expected, six teachers (one from each school) shared that they plan to teach the Engineering I and/or II course next year.

Of the teachers that will be teaching engineering in school year 2016-2017, three individuals shared that they felt confident after participating in the ESS and K-16. This included one teacher from Kaimuki who taught both courses this year. As one person shared, "I'm comfortable and I'm confident. I just need a lot more time to prepare everything I'm going to teach." Another person added,

> I'm confident too in both of them… The Engineering I, when I got my curriculum map from [Project Director], that was a big help and that's how I set up my lessons and my

> units. Same thing for Engineering II. Still a lot of work in progress for Engineering II, but we're getting there. Engineering I, I'm pretty much totally confident with.

Echoing this sentiment, the remaining teachers who were all new this year reported feeling fairly confident to teach Engineering I, but much less confident to teach Engineering II. One person mentioned,

> I think for Engineering I, I feel like with all of the materials and then hopefully you guys and the rest of the cohort answering questions if I have them throughout the year, that I would be pretty confident. But I'm definitely not confident about teaching the second course because we've only had this one course… I don't know how to go from 1 to 2.

Generally, it seemed as though teachers were more uncertain about the content that should be covered in the Engineering II course. This is illustrated by the following discourse:

Teacher 1: I need to have more sessions where we go into more content… I would see [Engineering II] being more technical and maybe more different skills that the kids have – either mechanical wise or using different tools. But I cannot see that Engineering II would be just EDP again. Not just EDP.

Teacher 2: Right. Which is what I think Engineering II should be – more math and more difficult concepts versus build something and then refine it and then Gantt chart and Pugh chart.

A third teacher helped to explain this confusion in stating, "We didn't look at [Engineering II]. She just gave us the standards. We didn't really go over what the curriculum for Engineering II would look like." It may be that greater clarity on the Engineering II curriculum will help to clarify what this course will cover and increase teachers' confidence teaching Engineering II.

Teachers also spent time discussing how the summer engineering course, offered through UHM and sponsored by the ESS and K-16 projects, will help to build teachers' confidence with the content needed for Engineering II. This course was created in response to teacher requests for more engineering content knowledge (see ESS Mid-Year Focus Group Report for more information). One person shared, "I'm teaching the Engineering II. I think I have a better understanding of the EDP process, but I like that we're going to be offered that summer course so hopefully that will also build my confidence in teaching the actual content part of fit." Another individual concurred, "Echoing what both [teachers] said, confident to teach the level 1, level 2 maybe not so much. But going to the summer class and seeing what those expectations will be at the college level will help me to see what it needs to look like going all the way through." Still, a third teacher brought up that the workbooks do not cover all types of engineering, so there is hope that they will be exposed to various activities for different types of engineering, including but not limited to mechanical and chemical engineering.

Engineering Success for the Engineering Pathway. Teachers imagined what a college-focused engineering pathway program might look like next year. In both focus groups, it was clear that teachers are excited to teach new courses and challenge their students, but some concerns remain at the level of the students, the individual schools, and the HIDOE. This being said, the following summary of their responses is intended to bring light to issues that lie outside of the realm of the ESS and K-16 projects. Although these projects have been remarkably responsive to teachers' feedback and requests (i.e. offering a summer UHM

engineering course), the nature of these issues suggests that these might be areas for teachers, schools, and the greater system to consider to ensure the success of this program.

Engineering success at the student level. First and foremost, teachers are excited to engage their students in the engineering design process and those who have already been teaching the EDP report that their students are engaged in the learning. As one participant shared, "I think the engineering classes should be like those kids literally saying, here's a problem, I'm going to engineer this. I thought that was really cool... That's kids using their engineering brains and I liked that." Teachers also talked about the potential of an engineering pathway as a way to introduce students to engineering and get them to consider some different career options. One such teacher proclaimed,

> What about the kids who are just like, I just want to figure it out... I think that this is a good program. It's like hey, I'm going to try this out. Maybe this is where I want to go? Maybe this isn't where I want to go? But what I would like to see with this academy is girls who took calculus their senior year, but weren't super stellar at it, just them trying it out and getting more kids exposed to [engineering] because maybe they do want to do it... That's what I would like to see.

In thinking about what teachers want their students to learn, both groups discussed student motivation to some extent. In one group, a couple of teachers commented on student motivation to take the higher level math and engineering courses required in the engineering pathway. In the second focus group, all teachers engaged in a conversation about how students with college aspirations plan to attend universities on the mainland. One person reported,

> I actually told some of my kids about that. That they have to get a B or higher and they would be automatically accepted into the College of Engineering, but every single one that I asked don't plan to go to UH Mānoa. So, when they told me that, I didn't see now how am I going to get that buy in from the students if this isn't going to help them in the way that we thought it was going to help them.

Another teacher at a different school agreed and responded,

> Until they find out how much it costs. We had a speaker who actually said I want everybody to stand up who is going to stay here on the island, and I'm sorry, but it was crazy... there were 3 people who were still sitting in their chairs in my class. All of those [other] people thought that they were getting off the island when they graduate from high school. I mean it's unreasonable for them to think that. As soon as they figure out how much it costs to go to college, they are going to be here... But they are not interested in UH at all.... They are like, oh no, I'm not going there.

In being solution focused, a couple of teachers pondered ways to increase student interest outside of the classroom. One person put forth,

> Looking at it as a job skill or a trade or anything that a student might pursue into the future... this project does a great job with teachers, but I don't think the stumbling block to getting more students involved is necessarily the teachers. I think it has a lot to do with leadership in schools and even counselors. How do they get educated on these

> types of things so that they are saying the right things to the students about why these skills are necessary or why they should pursue these things? I think that this project right now is addressing the teacher portion, but to really grow interest there are a lot of people along the way in levels of schools that impact students besides just us.

A second teacher and expanded this view in stating, "Maybe the words of the community too because a lot of the voices [students] hear are outside of the school." Last, one teacher strongly felt that the college pathway was not an incentive for high performing students who would gain access to the College of Engineering regardless of participation in the program. However, the evaluator felt that this individual may be misinformed. Clarifying the coursework and pre-requisites for the program would help individual teachers, other school personnel, and the greater community to see this pathway as a benefit for aspiring engineering students.

A couple of teachers revisited the mid-year discussion about the level of rigor needed to prepare students for college. As one proponent stated, "I think that the grant has a real open question about some of the technical skills that we need as teachers to really have the confidence to teach this beyond the process level... not for the kids to just understand the [EDP] process but for them to have some real math at a very very high level." This conversation was noticeably less than the mid-year due to the upcoming UHM summer engineering course. Looking at this issue from a different perspective, one teacher reminded the others that

> I feel like, and this is something that I need to work on in my class, that we are kind of over-simplifying engineering as a career for the students... And so I think maybe in our classes, we need to really remind them that you need to focus on science and math and it's rigorous and we're not hitting the rigor that you're going to need in the future.

Engineering success at the school level. The biggest concern at the school level had to do with how student interest and motivation affect enrollment, which in turn affect course offerings. One teacher started off the conversation in stating,

> I think it's so wonderful that the program offers automatic admission to the College of Engineering, but I'm afraid that the way that our system is set up, we will have too few students who have that opportunity. At best, we will have one class of 30 students who is on that math track - taking those higher level math... And then as they go through, not everybody will want to go into the engineering.

Another teacher at the same school continued, "We won't get the funding for it... If only 10 students are successful in the 4 years, which is a great thing, we can't run a class of 10. Our principals will not honor a class of 10. I've had an AP class denied at 12." This is a valid concern if a pathway into the College of Engineering exists, but students are not able to take the required courses.

Other school-level concerns reiterated issues with competency-based education and a need for individual schools to abandon efforts to combine multiple levels of a course into one class. The following quote summarizes the discussion that took place between two teachers at the same school,

> Competency based education is a different way of teaching... It allows you to be able to teach in stacked classes... And this competency based education that we're being led down the road to do, I don't see it as the answer to cranking out engineers. It's the answer to giving somebody a passing grade who breathes in my class.

According to teachers, stacked classes create a problem where students are not able to learn the standards associated with different levels of a core content area (i.e. biology, chemistry and physics). This raises serious issues about student learning and the intent for educational initiatives to do no harm that go far beyond the core competencies needed for an engineering pathway.

Engineering success at the HIDOE level. The last area of concern for teachers stems from a lack of alignment between learning standards and course offerings between middle and high schools. This was of particular concern to math and science teachers at multiple schools. As one person stated,

> Students that are coming into 9th grade are supposed to be taking Algebra I as soon as they come in and they're not competent to do that... They are creating a huge problem there because now your students don't actually get everything they're supposed to be getting in Algebra I because you can't teach it all because you're teaching them pre-algebra skills... You have to take everybody into the class and they're not all ready for it because it's a requirement... You can't get any credit for any course below algebra I in high school. They don't count as credits. So, even though they're not capable of doing Algebra I, they're not ready for Algebra I, they don't know how to do Algebra I, they don't have a chance of passing Algebra I in that first year, they have to take it. This is a DOE issue.

Another teacher went on to point out that the content standards for middle school do not even match up with the standards at the high school level. This person shared, "We did vertical alignments in our districts, so we said how come [students] don't come ready for [content area] in 9th grade? And they said well, our 8th grade standards are these and we don't necessarily have to make them [content] ready for you." A third teacher expanded the conversation to consider alignment with the expectations at the college level. This person said,

> I agree with what [teacher] is saying because with NGSS my concerns are the lack of the content specific standards because it is a lot of the problem based learning. I'm afraid that the critical skills and the content is not there... Where is the stoichiometry in the NGSS? It's embedded, but it's not specific, and so if I decide as a classroom teacher not to teach stoichiometry, [students] are at a loss at the college already.

Conclusions

Despite the challenges and suggestions brought up by participating teachers, it is important to frame these in light of the current project and look to the future. Teachers who participated in the ESS and K-16 projects have consistently reiterated their appreciation for these projects, their excitement about the engineering design process, and their gratitude to the Project Director and staff. As one person shared, "[Project Director] has been wonderful. I

wish she could help our principal understand some of the issues because I think [Project Director] had a better understanding of the things that we went through then the principal did and it was him leading us to where we were." A second participant disclosed,

> I think it was really awesome how we had a focus group and there's actual response to things that we brought up. I don't see that often in anything. Ever! And so especially in something in education, we really don't see anyone responding to our concerns or our suggestions and so that was validating and also inspiring and also a good reminder to keep hope that people actually can make changes to things, they just have to choose to do it. Thanks.

Clearly, the projects established a level of trust with teachers that encouraged them to bring up potential challenges beyond these grants because the Project Director and staff truly care. In thinking about the time it takes to develop these kinds of relationships, teachers who had been with the project for three years tended to agree that their participation had been long enough, while others who were new to the project wished that their participation could continue. The following section summarizes the main findings from the focus groups, as well as some considerations for future projects and potential next steps.

Summary of Key Points

- Teachers reported that participation increased their understanding of the EDP and confidence teaching the Engineering I course curriculum (ESS Objectives 2 and 3)

- A number of teachers discussed changes in their approach to teaching such as greater collaboration to integrate different content areas and increased efforts to be project based (ESS Objective 3 and K-16 Objective 3).

- Teachers reported that the most valuable aspects of the project were the:
    - Work sessions and curriculum resources (ESS Objective 2 and K-16 Objective 2)
    - Support offered by the Project Director and staff
    - Developing and implementing curriculum units that focused on the EDP
    - Going through design challenges during the work sessions

- Participants perceived the following project activities to be the most helpful for collaborative unit development:
    - Working with other teachers who teach the same content area
    - Receiving feedback from project staff and peers
    - Hearing from other teachers who had more experience with the project
    - Working with teachers from other content areas

- All schools had at least one person who agreed to teach the Engineering I and II courses (K-16 Objective 4).

- Teachers are excited to teach new courses and challenge their students, but some concerns remain at the level of the students, the individual schools, and the HIDOE.

Recommendations

Considerations for Future Projects:

- Teachers made the following suggestions to enhance future projects (K-16 Objective 5):
  - Have teachers design, implement, and share curriculum units
  - Assign one teacher as the lead for unit development (preferably the engineering teacher)
  - Provide time to collaborate during work sessions
  - Replicate the ESS model of professional development which scaffolds focused work sessions on each step of the EDP, time to collaborate on unit development, and exposure to a wide variety of design challenges
  - Create a mechanism to share resources and experiences beyond the project

Considerations for the Engineering Pathway:

- Student level suggestions:
  - Consider avenues to increase student interest and motivation in STEM through other school personnel and the greater community
  - Remind students who are interested in engineering at the college level to remain focused on building their math and science skills

- School level suggestions:
  - Offer course requirements for the engineering pathway program in ways that maximize enrollment and maintain learning objectives

- HIDOE level suggestions:
  - Assess the practicality of high school course requirements in light of standards alignment between the middle and high school levels
  - Consider articulating content-specific standards to assure that students are prepared for college and beyond

Engineering Success in STEM (ESS) and the K-16 Engineering Pipeline
Teacher Survey Report
July 10, 2016

Overview

This report summarizes the impact of two concurrent and related professional development projects on participating Hawai'i Department of Education (HIDOE) public high school teachers. The Engineering Success in STEM (ESS) and the K-16 Engineering Pipeline: Engineering Success in STEM (K-16) projects were developed by Chaminade University and funded by Office of Naval Research grants. The ESS project concluded its third and final year in SY2015-2016. This project provided professional development to facilitate teacher understanding of the EDP as well as the development and implementation of standards-based STEM curriculum units that incorporated the engineering design process (EDP) through science, technology, engineering, and math (STEM) content areas. The second K-16 project provided additional supports for one year to institutionalize an engineering pathway between the HIDOE and the University of Hawai'i at Mānoa College of Engineering (UHM).

In Year 3 of the ESS, the project focused on providing services to a greater number of high school teachers in six complex areas to enable more high schools to participate in the engineering pathway to UHM. In total, six public high schools participated: Kaimuki High School was in its third year of participation through the ESS and five other schools were in their first year with the ESS and K-16 projects (Castle, Kealakehe, Leilehua, Moanalua, and Pearl City high schools). Over the course of their participation, teachers had access to a comprehensive array of professional development supports. These included:

1. Work Sessions delivered by Chaminade University and the University of Hawai'i College of Engineering (7 sessions/year);
2. Teacher-directed Work Days to design and plan STEM curriculum units that address the EDP, HIDOE standards, and benchmarks (2 substitute days/year);
3. Mentorship by curriculum development experts from Chaminade University (as requested); and
4. Meetings with content experts including UHM College of Engineering staff, U.S. Navy personnel, and other professional engineers (as requested).

The impact of the professional development activities on teachers was assessed using a mixed-method approach that included surveys and focus groups. The teacher survey was designed to gather information about the projects' progress toward meeting specific objectives and desired outcomes. The ESS project sought to develop a deep understanding of the engineering design process (ESS Objective 1) by increasing teachers' knowledge and confidence with the EDP. To further support the ESS, the K-16 project aimed to pilot test the teacher training session curriculum and prepare high school teachers to teach the required engineering core courses within the Engineering Pathway (K-16 Objective 2). To examine this objective, the survey instrument measured teachers' attitudes toward engineering, personal and social beliefs, and current teaching practice.

The findings of ESS Year 1 and 2 are briefly summarized to provide some historical context. In Year 1, teachers' knowledge of the EDP increased significantly between pre and

post-tests and ratings for attitudes and confidence also went up although gains were not significant (please see the 2014 ESS Teacher Survey Report for more information). In Year 2, approximately half of the participating teachers were new to the project and ratings for teacher knowledge, personal and peer attitudes, and confidence increased significantly over the course of Year 2. An item analysis revealed that the project had the greatest impact on teachers' confidence and attitudes toward certain EDP steps: Creating a plan, Defining the specifications, Testing the prototype and Improving the design. Additionally, teachers who participated for two years provided higher ratings for their knowledge and confidence at the beginning of Year 2, but these differences largely disappeared by the end of the year. This illustrated that the professional development offered was effective in helping the new teachers catch up with their peers. Ratings for current teaching practice also increased significantly, but only for teachers who participated for two years. This indicates only the teachers who participated for two years increased the extent to which the EDP was practiced in their classrooms.

Although the ESS project utilized the same survey for three years, planned comparisons across Years 1, 2 and 3 were not possible due to substantial changes in school and teacher participation in Year 3. Therefore, comparisons will focus on the differences between teacher ratings in the Fall and Spring of Year 3 because the sample of teachers who participated for all three years is too small to have the statistical power to detect meaningful effects.

Methods

Data Collection

The online survey was administered to all participants at the beginning and end of SY2015-2016. Participation was mandatory, but responses were completely confidential. Survey response rates are presented in Table 1.

Table 1. Survey Response Rates

	Year 3	
	N	**%**
Pretest	15	100%
Post-test	15	100%

Participants

Participants included 15 public high school teachers who represented the content areas of math, science, engineering, career and technical education (CTE), industrial and engineering technology (IET), and STEM resource support specialists. Three teachers (20%) were in their third year of participation with the ESS and 12 (80%) were new to the ESS and K-16 projects. On average, participants reported teaching for 11 years and taught at their respective schools for 9 years. A majority of teachers held a Master's degree (11, 73%) and

the remaining teachers held a Bachelor's degree (4, 27%). A large proportion of teachers were certified (11, 73%) and a most were highly qualified under No Child Left Behind (13, 87%).

Instrument

The survey instrument was designed to measure teacher knowledge, interest, confidence, and implementation of the EDP. The psychological concepts of interest, confidence, and implementation align well with the *theory of planned behavior* (TPB), one of the most frequently cited and influential models for the prediction of human social behavior based on attitudinal variables (Azjen, 2011). According to the TPB, if an individual perceives a behavior to be positive (attitudes), believes that their peers want them to perform that behavior (subjective norms), and thinks that they can successfully perform that behavior (control and self-efficacy); then they are more motivated and more likely to do so (behavioral intentions). Based on this theory, survey items were designed to measure engineering knowledge, personal attitudes (as a measure of teacher interest), peer attitudes (as a measure of social pressure or subjective norms), confidence (as a measure of self-efficacy), and teaching practice (as a measure of implementation).

In total, the survey covered five domains of interest. The first domain included nine items to measure knowledge of engineering design principles and related careers. The second domain included 10 items assessing personal attitudes toward teaching engineering, the third domain included six items examining peer attitudes, and the fourth domain included eight items measuring teacher confidence. The fifth domain included 11 items about current teaching practice. All items asked teachers to rate to what extent they agreed with statements about knowledge, attitudes, confidence, and teaching practice. Response choices were rated on a Likert scale (1 = Strongly disagree, 2 = Disagree, 3 = Agree, 4 = Strongly agree, and Not Applicable). The items were based on, or adapted from, previously created instruments or reports that included item descriptions (International Technology Education Association, 2007; Garfield, delMas & Zieffler, 2012; and others). The instrument also collected demographic information about teaching experience, education level, and teacher qualifications.

The internal consistency of the survey was excellent with a reliability estimate of $\alpha = .95$ for the instrument. The internal consistency of each domain was also acceptable. Reliability estimates for the five domains were $\alpha = .84$ for knowledge, $\alpha = .84$ for personal attitudes, $\alpha = .74$ for peer attitudes, $\alpha = .89$ for confidence, and $\alpha = .88$ for teaching practice. All items were retained in the final analyses as item correlations and reliability estimates did not warrant the removal of any survey items.

Analyses

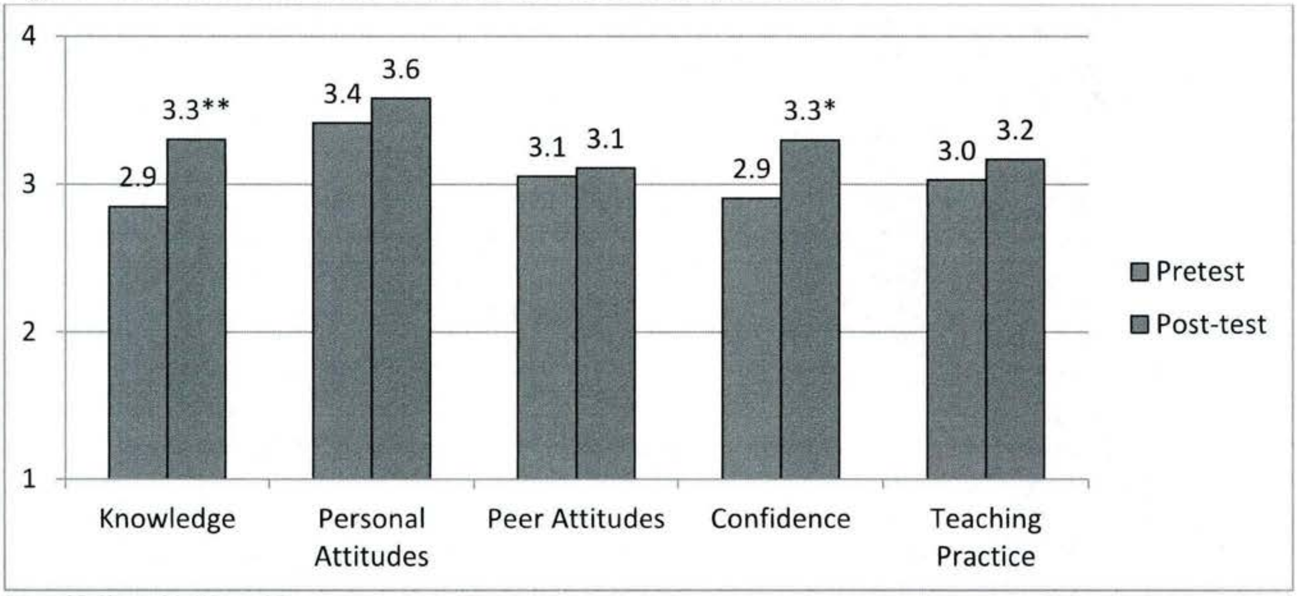
Items included in each domain were averaged to create a mean score for each domain. Missing data was deleted on a case-wise basis (meaning teacher scores were retained as long as there was data for all data points included in a particular analysis). Paired t-tests were used to test the effect of the independent variable (IV) Time (pre and post) on the dependent variables (DV) of knowledge, personal attitudes, social attitudes, confidence, and self-reported teaching practice.

Results

Teacher Changes in Year 3

The results of the analysis show a positive trend with teachers providing higher ratings for all survey domains by the end of Year 2 (see Figure 1). Significant increases were observed for teacher knowledge of engineering design process and careers ($p \leq .01$) and confidence teaching the EDP and incorporating engineering content into their curriculum ($p \leq .05$). Personal attitudes, peer attitudes, and self-reported teaching practice increased slightly, but differences were not significant. See Table 2 for more detailed information.

Figure 1. Mean of Pre and Post-tests for each Survey Domain



* $p \leq .05$, ** $p \leq .01$, *** $p \leq .05$

Table 2. Results of the Paired T-test for Teachers in Year 3

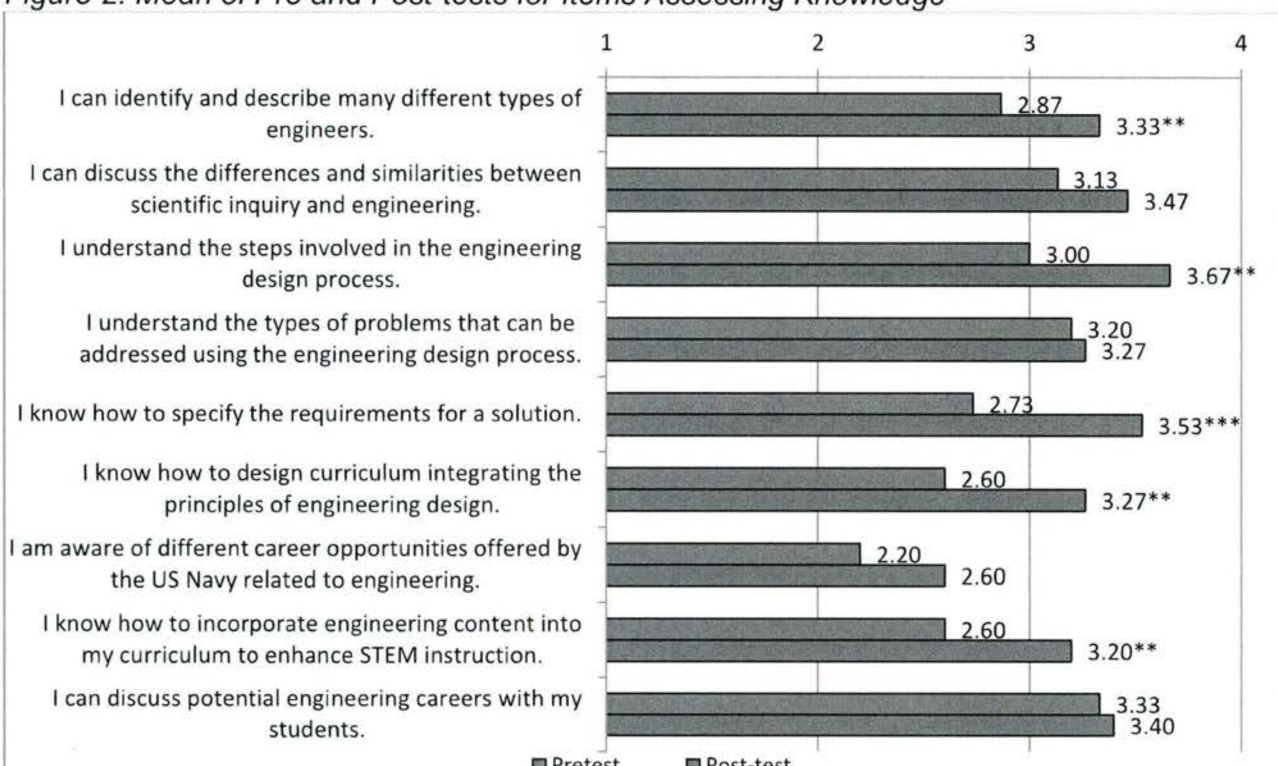
Domain	Test	*M*	*SD*	*df*	*t*	*p*
Knowledge	Pretest	2.85	0.64	14	-3.32	.01
	Post-test	3.30	0.45			
Personal Attitudes	Pretest	3.41	0.41	14	-1.85	.09
	Post-test	3.58	0.36			
Peer Attitudes	Pretest	3.06	0.27	14	-0.57	.58
	Post-test	3.11	0.37			
Confidence	Pretest	2.91	0.52	14	-2.74	.02
	Post-test	3.30	0.46			
Teaching Practice	Pretest	3.03	0.49	14	-1.39	.19
	Post-test	3.17	0.59			

Note: M = mean, SD = Standard Deviation, df = degrees of freedom, t = t-test statistic, p = significance level

A deeper examination of the differences between teacher pre- and post-test ratings was conducted for each survey domain where significant changes were observed. This information was used to identify areas where teachers made significant gains to inform future projects. An item comparison using post-hoc paired t-tests is presented below.

Knowledge. An item comparison for teacher knowledge of engineering design principles and careers is presented in Figure 2. Increases in teacher self-reported knowledge were observed for all items included in this domain. Greatest gains were observed for: a) Specifying requirements for a solution, b) Understanding the steps of the EDP, c) Designing curriculum integrating the EDP, and d) Incorporating engineering content into STEM instruction. Unlike the results for Year 2, teacher knowledge of potential engineering careers and US Naval career opportunities did not increase significantly. Teachers provided the highest ratings for these items in Year 2. However, it should be noted that knowledge of potential engineering careers was rated fairly high on the Pretest. This was also the case with understanding the types of problems that can be addressed using the EDP.

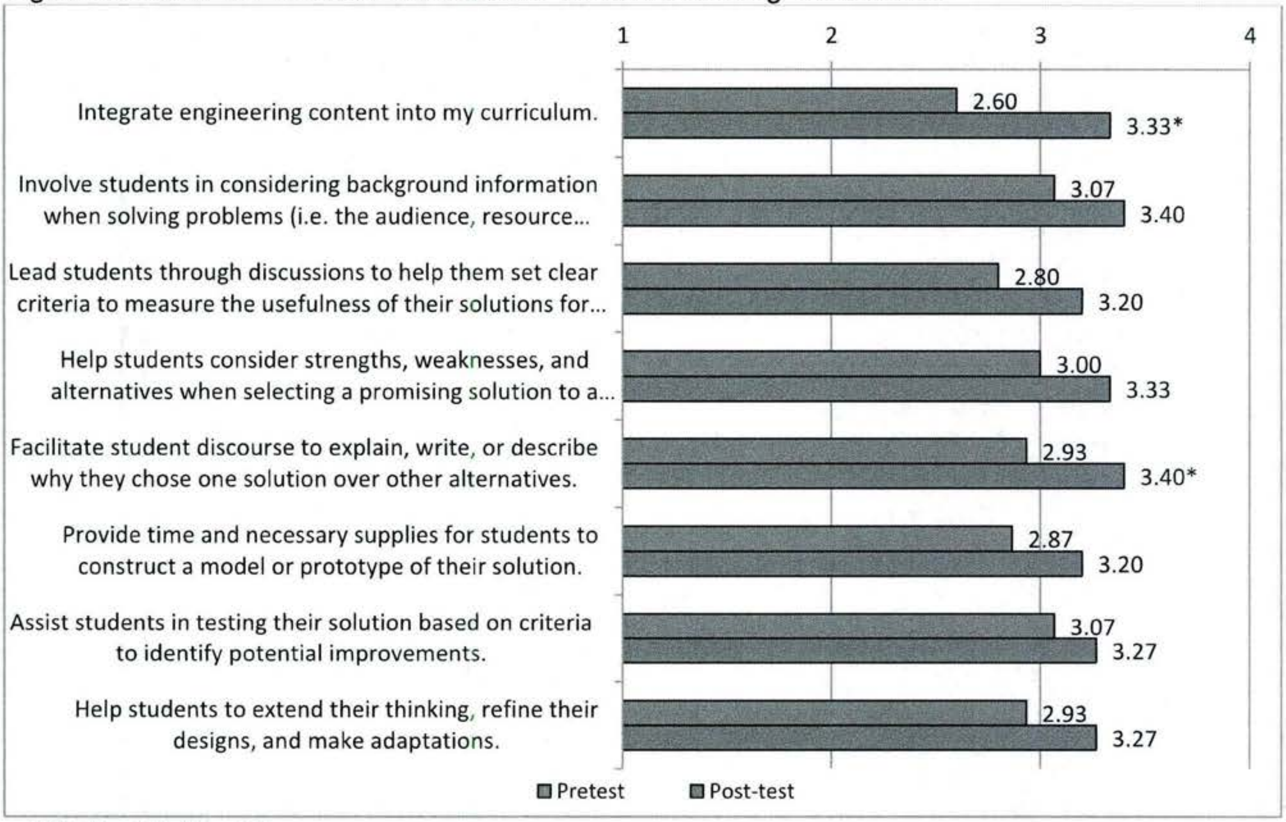
Figure 2. Mean of Pre and Post-tests for Items Assessing Knowledge



* $p \leq .05$, ** $p \leq .01$, *** $p \leq .05$

Confidence. The item comparison for teacher confidence with the EDP is presented in Figure 3. Improvements were observed for all items in this domain. Significant increases were reported for teacher confidence with: a) Integrating engineering content into their curriculum, and b) Facilitating student discussions about why a particular solution was chosen over others.

Figure 3. Mean of Pre and Post-tests for Items Assessing Confidence



$p \le .05$, ** $p \le .01$, *** $p \le .05$

Conclusions

The results of the ESS teacher survey provide evidence that the project achieved the desired outcomes to increase teacher knowledge, personal and peer attitudes, confidence and implementation of engineering concepts and principles. The analysis revealed that ratings of teacher knowledge and confidence increased significantly over the course of Year 3. Although positive gains were observed for teacher interest (personal and peer attitudes) and teaching practice, differences were not significant. To help explain these findings, it should be noted that teacher ratings for personal attitudes were relatively high (3.4) at the pretest (higher than any other survey domain) which could limit the potential for significant change because of a ceiling effect (the highest possible rating is a 4.0). Regarding self-reported teaching practice, it is likely that these results are due to the fact that the ESS and K-16 projects did not require implementation for teachers who were in their first year of participation (12, 80%).

In considering the item analysis, professional development provided in Year 3 had the greatest impact on teacher knowledge with significant positive change observed on a majority of the items included in this domain. Noticeably, items about knowledge of engineering career did not increases significantly as they had in Year 2. It may be important to continue to include this as a topic in the professional development work sessions to assure that new teachers are

able to pass this important information on to their students. Last, in considering the analysis of items included under teacher confidence, there may be a connection between implementation and teacher confidence that contributed to fewer items being rated as significantly higher on the post-test. Most of these items were designed to assess confidence with specific steps of the EDP, many of which teachers may not have had an opportunity to experience if they did not voluntarily choose to implement an EDP in their first year of participation. Therefore, implementation may be key in increasing teacher confidence for future projects.

In summary, the professional development opportunities offered through the ESS significantly and positively impacted teachers' knowledge and confidence with the EDP. Overall, the results are still positive, with increases between pre- and post-test ratings for teacher knowledge, personal and peer attitudes, confidence and implementation of the EDP. Ratings in these areas were also fairly high on average (≥ 3.0 for all survey domains). According to the theory of planned behavior, high ratings for personal attitudes, peer attitudes, and confidence may lead to greater intentions to implement the EDP with students beyond the life cycle of the ESS and K-16 projects.

COLLEGE-FOCUSED ENGINEERING PATHWAY PROGAM OF STUDY

Required Courses	Engineering Pathway Courses (Grades of B or Better)	Electives *Application/Content Courses*	Other Program Requirements	Outcome of Meeting Program of Study Requirements	K-16 Outcome
Mathematics: **4 credits** **(Grades of B or Better)** ~ Algebra I ~ Algebra II ~ Precalculus/ Trigonometry ~ Calculus (AP/IB/Running Start) **Science:** **4 credits** **(Grades of B or Better)** ~ Biology 1 (or accepted AP/IB equivalent) ~ Chemistry (AP/IB/Running Start) ~ Physics (AP/IB/Running Start) ~ Science Elective **English:** **4 credits** **Social Studies:** **4 credits** **Physical Education:** **1 credit** **Health:** **0.5 credit**	**Grade 9** TIC5010 Industrial and Engineering Technology Core **Grade 10** TIU5810 Engineering Technology I **Grade 11** TIN5623 Engineering Technology II **Grade 12** XAT1000 STEM Capstone	**Mathematics:** ~ Probability/Statistics ~ AP Statistics **Science:** ~ AP Environmental Science **Engineering Program of Study Cluster Courses** TIU5710 Electricity & Electronics TIU5310 Design Technology I TIN5320 Design Technology II TIN5520 Cyber Security TIU5713 Networking Fundamentals and LAN TIN5716 WAN and Networking Architecture TIU5510 A+ Certifications Introduction			

Personal Transition Plan 0.5 credit		TIU5511 A+ Certifications Computer Systems TIN5512 A+ Certification Operating Systems TIN5513 Internship TIU5620 Electronic Technology I TIN5623 Electronic Technology II	**Acceptance into UHM**	**Acceptance into College of Engineering UHM in a Declared Engineering Major**	**Engineer**

<u>Total Credits = 24</u>

MEMORANDUM OF UNDERSTANDING
BETWEEN
THE COLLEGE OF ENGINEERING, UNIVERSITY OF HAWAI'I AT MANOA
AND
THE STATE OF HAWAI'I DEPARTMENT OF EDUCATION
REGARDING
College-Focused Engineering Pathway to Acceptance at the College of Engineering, University of Hawai'i at Manoa

This Memorandum of Understanding ("MOU") is between the College of Engineering, University of Hawai'i at Manoa (CoE-UHM) with its principal place of business at 2540 Dole Street, Holmes Hall 240, Honolulu, Hawai'i 96822 and Hawai'i State Department of Education and its affiliates, (HIDOE} with its principal place ofbusiness located at 1390 Miller Street, Honolulu, Hawai'i 96813.

I. Purpose

The purpose of this agreement is to establish a formal partnership between HIDOE and CoE-UHM for the purposes of a single initiative, the *College-Focused Engineering Patlm•ay to Acceptance at the College of Engineering, University of Hawai'i at Manoa.* This MOU seeks to clearly identify the requirements and necessary preparation for Hawai'i high school students to be accepted directly into a designated engineering major in the CoE-UHM, an engineering course of study accredited by the Accreditation Board for Engineering and Technology (ABEn.

II. Background

The CoE-UHM has supported the development of a college-focused engineering pathway for Hawai'i public high school students to enter its professionally accredited engineering program. The pathway concept resulted from a collaboration between HIDOE and CoE-UHM, and was funded through an Office ofNaval Research grant administered by the Director of the Office ofNaval Research Project and Educational Leadership Program at Chaminade University. Through this collaborative effort the following milestones were achieved:

- Developed college-focused engineering pathway program requirements for high school students to successfully matriculate and pursue a degree at the CoE-UHM.
- Worked on the development of Engineering Technology I and II standards.
- Developed HIDOE approved Engineering I and II high school courses. These courses are consistent with the anticipated knowledge base for CoE-UHM entry level engineering course objectives.

III. Collaboration

CoE-UHM and HIDOE will each accept the following roles and responsibilities to meet the goals of this agreement to the extent practical and authorized by law and State policies:

Engineering Success in STEM

A. College of Engineering, University of Hawai'i at ManoA

1. Designate a point of contact (POC} within CoE-UHM to administer the College-Focused Engineering Pathway program to acceptance at the College of Engineering, University ofHawai'i at Manoa Initiative.

2. Provide an annual summary ofCoE-UHM public school freshmen enrollment data including students identified by HIDOE as successfully completing the College-Focused Engineering Pathway program.

3. CoE-UHM will summarize the College-Focused Engineering Pathway program data gathered from the review of applications from all public high school students accepted to the University ofHawai'i at Manoa who have designated an engineering major and self-reported that they are enrolled in the College-Focused Engineering Pathway program on their application. This data will confirm that CoE-UHM has accepted students who met the following requirements:

   - Gained admission into the University of Hawai'i at Manoa.
   - Met HIDOE College-Focused Engineering Pathway Program of Study requirements as provided by the HIDOE. The list of high school student graduates who have successfully met all HIDOE College-focused Engineering Pathway Program of Study will be provided to the CoE-UHM POC. The College-Focused Engineering Pathway Program of Study requirements are included in Attachment 1.

4. Coordinate and facilitate an annual meeting with HIDOE POC.

B. Hawai'i State Department of Education

1. Designate a point of contact (POC) within the HIDOE to administer the College-Focused Engineering Pathway to Acceptance at the College of Engineering, University ofHawai'i at Manoa Initiative.

2. Disseminate information and announcements regarding the program to HIDOE administrators, specialist, and teachers.

3. Provide the list of public high school graduates identified by the HIDOE as having successfully completed the HI DOE's College-Focused Engineering Pathway program.

4. Provide data to the CoE-UHM POC on:1) schools adopting the College-Focused Engineering Pathway program, and 2) schools teaching Engineering I and II courses.

5. Develop strategies with the CoE-UHM to monitor and assess program effectiveness in order to optimize student success

IV. General (Standard Language – keep intact)

A. This MOU is strictly for internal management use of each of the parties. It is not legally enforceable and shall not be construed to create any legal obligation on the part of either party. This MOU shall not be construed to provide a private right or cause of action for or by any person or entity.

B. This MOU can be amended by either party should university admission requirements and/or HIDOE requirements change. Consideration of high school students enrolled in the program will be made.

C. This MOU can be terminated by either party at any time by providing notice in writing to the other party.

D. This MOU in no way restricts either of the parties from participating in any activity with other public or private agencies, organizations or individuals.

E. This MOU is neither a fiscal nor funds obligation document. Nothing in this MOU authorizes or is intended to obligate the parties to expend, exchange, or reimburse funds, services, or supplies, or transfer or receive anything of value.

F. This agreement is effective for five years from the time of signing. The parties to this agreement will review the program one year prior to the expiration of the agreement to ascertain whether alterations are required.

G. The terms of this agreement are subject to prevailing University ofHawai'i and HIDOE policies.

UNIVERSITY OF HAWAI'I AT MANOA

Robert Bley-Vroman 3/14/16

Robert Bley-Vro an date
Interim Chancellor

[redacted] 3/1, /16

Reed Dasenbrock date
Vice Chancellor for Academic Affairs

P Crouch 3/tt(/6

Peter Crouch date
Dean, College of Engineering

THE STATE OF HAWAI'I DEPARTMENT OF EDUCATION

KMatayoshi MAR 10 2016

Kathryn S. Matayoshi date
Superintendent

COLLEGE-FOCUSED ENGINEERING PATHWAY PROGAM OF STUDY

Required Courses (Grades of B or Better)	Engineering Pathway Courses (Grades ofB or Better)	Electives *Application/Content Courses*	Other Program Requirements	Outcome of Meeting Program of Study Requirements	K-16 Outcome
Mathematics: 4 credits (Grades of B or Better) - Geometry I or2-Year Integrated Common Core Sequence - Algebra II - Precalculus/ Trigonometry - Calculus (APIIB/Running Start) Science: 4 credits (Grades ofB or Better) - Physical Science or Other Sci. Course - Biology 1 (or accepted AP/18 equivalent) - Chemistry (or accepted AP/18 equivalent) - Physics (or accepted AP/18 equivalent) English: 4 credits Social Studies: 4 credits	Grade 9 TIC5010 Industrial and Engineering Technology Core Grade 10 TIU5810 Engineering Technology I Grade 11 TIN5623 Engineering Technology II Grade 12 XAT1000 STEM Capstone	Mathematics: - Probability/Statistics - AP Statistics Science: - AP Chemistry - AP Physics - AP Environmental Science Engineering Program of Study Cluster Courses TIU5710 Electricity & Electronics TIU5310 Design Technology I TIN5320 Design Technology II TIN5520 Cyber Security TIU5713 Networking Fundamentals and LAN TIN5716 WAN and Networking Architecture TIU5510 A+ Certifications Introduction TIU5511 A+ Certifications Computer Systems	Acceptance into UHM	Acceptance into College of Engineering-UHM in a Declared Engineering Major	Engineer

Physical Education: 1 credit Health: 0.5 credit Personal Transition Plan 0.5 credit	TIN5512 A+ Certification Operating Systems TIN5513 Internship TIU5620 Electronic Technology I TIN5623 Electronic Technology II		

Total Credits= 24